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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

FACE HARDENED ARMOR.

By LIEUT. A. A. ACKERMAN, U. S. Navy.

PREFACE.

The writer has long been impressed with the fact that the mode of resistance commonly ascribed to face hardened armor is incorrect. It seems that many have applied to it the theory upon which the development of compound armor was based. That is, the hard face was intended to smash the projectile without allowing penetration ; the body and back was to assist the face under impact, and to hold it together even after it had cracked and failed.

Modern improved projectiles are seldom crushed from the point. The point may be fused and abraded or chipped off in breaking up the hard face, but actual disintegration of the projectile only occurs when the resistance that the plate is able to bring on the area of the shell in contact with it is sufficiently great to suddenly check the shell and cause it to break up over its weakest lines through its own inertia. Failure at the point may, however, arise even with low velocities, when the resistance of the plate is less local, provided the energy of the shot is incapable of effecting penetration, or in the case of inferior projectiles.

The usual action of the hard face, however, is that through its inability to bend or flow, it prevents the displacement of the more plastic metal beneath it towards the front, and thus brings the resistance of the whole thickness of the plate to bear before the projectile can advance.

The important retarding influence of the fragments of the hard face carried in by the projectile, is seen in the easier perforation obtained by projectiles whose ogivals are protected by soft steel caps. The cap appears to act as a lubricant or sleeve, covering the asperities of the hardened metal. It is necessary for the cap to be driven into the plate to derive any advantage from it. Doubtless, when thus confined this soft metal transmits pressure as rigidly as the projectile itself, but being capable of flowing, the steel slips through it comparatively unharmed. It is believed that a thicker hardened surface, undulated to prevent or limit flaking, will cause the projectile to carry in sufficient of the hardened face to render the cap incapable of performing the work required of it without increasing its size to a prohibitory extent.

The writer has much for which to thank the officers with whom he has been associated in the Bureau of Ordnance in the way of information. Mr. Millard Hunsiker, now in charge of the manufacture of armor at the Carnegie Steel Company's works, at Homestead, has also kindly placed at his disposal valuable information. He also owes considerable to the Inspectors of Ordnance and officials at the works of the armor makers. These gentlemen are in no way responsible, however, for the conclusions reached. It has been the intention of the writer throughout to avoid discussing those technical details which have been developed by and are the property of the manufacturer rather than the patentee, and by means of which alone the process of face hardening can be made a commercial success.

SECTION I.

HISTORY AND MANUFACTURE.

Face hardened armor is the direct outcome of efforts to avoid the failures resulting from attempts to temper homogeneous steel plates of sufficiently high carbon to give a very hard face. It is theoretically the perfect armor plate, and doubtless would have been developed long ago had that theory only been enunciated; for the various steps followed in its manufacture, except in certain details, have long been known to the metallurgical world.

Lieutenant Jacques makes the following statement in a recent discussion of the armor problem: "We will not enter here into a discussion of the merits of those who have succeeded in getting their names attached to the various patented methods of surface hardening, but hope that those who deserve it will get the pecuniary benefit. Ellis treated the first thick plate many years ago; Harvey revived this method, and with the assistance of the Navy Department secured patents which received attention from abroad because of the prominence our Navy Department gave them."

The writer does not believe that Mr. Jacques intends to imply that the Navy Department has the power to obtain or assist to obtain an illegal patent. The assumption that Mr. Harvey revived the Ellis patent is not correct. The old cementation process was carried on usually in cast iron or fire-clay pots at a much lower temperature than that now employed. Had Mr. Harvey proposed merely to cement or convert steel at a temperature above that of molten cast iron, a temperature which would soon have destroyed the old cementation pots, there would still have been considerable novelty in the claim. But Mr. Harvey proposed to do something more by using this high temperature: he proposed to improve the steel, to impart to ingots or other objects of low steel, such as Bessemer steel, the qualities of refined crucible steel! That he succeeded in this, and that his process is in this respect one of a number somewhat akin to it by which inferior steel is improved, must be known to every steel maker. Whether this particular process is essential to the cementation of such high grade material as that of which armor is manufactured, is a different question. It is certain, however, that the Harvey patents cover the process when carried on at that high temperature.

There is an error of minor importance in the article of Lieutenant Jacques above mentioned. The title of Figure "F," Bethlehem 17-in. N-Steel Carbonized, Indiana's Barbettes," is incorrect. Later, in describing Figure "Y," the attack of the same plate by Johnson capped shot, he again speaks of it as carbonized. This was not the case, and its perforation should not be charged against face hardened armor; had the Indiana's 17-inch Barbette plate been face hardened, the premium velocity shot would have smashed on it, as it did on the "Massachusetts" Barbette, instead of perforating it with ease.

The writer has the greatest respect for the energy and ability of Mr. Ellis, but if credit is to be given for the cementation of armor, he must share the honor with others.

We learn in Lieutenant Very's "Development of Armor for Naval Use" that early in 1863 a Mr. Cotchette submitted the following armor proposal to the English Iron Committee: "Upon an armor plate, say 3 inches thick, weld a surface of blistered steel ¾ of an inch thick; or 'convert,' to a depth of ¼ of an inch, the face of an armor plate 3½ inches thick, the plates being subsequently passed through a pair of rolls for consolidation and to reduce the blisters. The face of the plates could then be hardened."

As early as 1867, Jacob Reese, of Pittsburg, Penn., in patenting a cementation compound, proposed cementing and hardening the surface of armor plates. No attempt appears to have been made, however, to carry out his proposition. Ten years later, John D. Ellis patented an armor face hardening process in which a plate wholly of soft iron or having a steely part on either one or both faces had one or both of these surfaces cemented with charcoal in an ordinary converting furnace. This cementation might be effected either before or after the plate was reduced to its finished size.

In the same year, 1877, the Cammell-Wilson patent was allowed, in which two-fifths of the back of a hard steel plate was decarburized and softened, leaving the face hard and strong. The same firm at this time tempered low steel plates by plunging them in water, which rendered them tougher and more tenacious than when cooled in the air.

In August, 1877, the first Wilson compound plate was tested; this plate had a steel face and a four-inch wrought iron back.

In 1878, Wilson proposed soldering the steel face to the iron back by means of tin, zinc, spelter or bronze (a perfectly feasible method, by the way, which may yet be employed to secure thin armor to the ship). This steel face was to be formed of a number of hexagonal or other shaped pieces, in order to localize fractures.

Whitworth, too, proposed, for the same purpose, securing hexagonal plates of very hard steel to a softer back by means of screws.

At the Portsmouth trial of 1888, the "Jessop" plate consisted of a three-inch front cast steel plate, composed of twelve separate pieces of very hard cast steel fastened in a special manner to the seven and one-half inch rear piece of soft cast steel. The theory was that the laminations of the outside plate would localize destruction and prevent the extension of cracks through the plate. This theory was found to be correct.

Thus far there seemed to be no consideration given to a mean between hard steel, containing about one per cent. of carbon, and which cracked and peeled from the backing, and soft wrought iron, which allowed perforation. The fact that steel could be made sufficiently *tough* to resist equally as well as compound armor without cracking, although claimed by Schneider, was generally denied by armor makers. No wonder that, under these circumstances, certain authorities made the assertion that physical characteristics had nothing to do with ballistic resistance.

In 1889, the attention of Commander W. M. Folger, U. S. N., the Inspector of Ordnance at the Naval Gun Factory, was attracted by a description of the Harvey process as applied to engraver's plates. At that time it was difficult to obtain steel suitable for gas check disks on account of its cracking in tempering, and Commander Folger concluded to try the Harvey process in obtaining the desired steel. A number of sets of rough steel disks were accordingly Harveyed, machined, and tempered, in a most satisfactory manner. Efforts were then made to Harvey a number of small caliber armor-piercing shell, the manufacture of which, in this country, was meeting with very slight success at that time. This attempt was made by grading the carbon from point to base in a foundation billet of mild steel afterwards forged into a shell. The carbon shell were, however, unable to compete with those containing chromium, and no great success was attained until long afterwards.

Commander Folger then decided to apply the process to armor by bringing the carbon in the face of a 28 per cent. carbon plate up to a point that would take a chill; the low carbon center and back retaining their softness. In this way he believed that the plate could be uniformly heated and cooled throughout, leaving it free from structural strains and with the minimum amount of distortion, defects which had been found to be very serious in certain tempered French plates of homogeneous steel. It will be seen that this was really an application of the Ellis process at a temperature higher than that usually employed in cementation.

The first experiment was not a success; the carbon penetrated three inches in depth, far beyond the reach of a true chill; but while attaining a percentage of 1.05 C at the surface, it fell immediately to 0.68 C. In consequence, the plate, which was only six inches thick, through being hard rather than strong over its front half, lost much of its extensibility and toughness, while the comparatively low percentage of carbon below the surface film prevented anything more than a very superficial chill.

This plate was tested in June, 1890. Excellent 6-pdr. armor-piercing shell made no impression upon it, but a 4″ A. P. shell weighing 36 lbs., and moving with a velocity of 1890 ft. s., broke it into four nearly equal fragments. The shell failed to penetrate; it merely crushed the face in 1.25″ and then broke up.

Two problems connected with the tempering of armor plates appeared prominent at this time: First, the avoidance of distortion; second, the rapid extraction of heat in order to carry the chill farther into the metal. An effort had been made to overcome the first difficulty in the autumn of 1889 by a spray apparatus designed by the writer to cool the plate uniformly. This consisted of pipes radiating from a central feeder; on the upper sides of these were the spray holes gradually diminishing in size from the center to the ends. In this manner it was hoped to so regulate the volume of spray as to cool the center of the plate, surrounded as it was on all sides by hot metal, at the same rate of speed as the edges. This apparatus, however, being applied to only one side of the plate, did not overcome the difficulty.* The spray pressure employed was over fifty lbs. per square inch. In tempering shell it had been noticed that the metal originally smoothly finished

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* Under the date of August 12, 1873, Herman Urban, of Cincinnati, Ohio, patented an improvement in apparatus for tempering steel plates and similar articles. This apparatus consisted of spray boxes, to which the chilling medium was introduced under considerable pressure, placed one on each side of the plate to be tempered. In this way the metal was not only expeditiously and uniformly chilled, but through cooling regularly from both faces there was not the slightest tendency to buckle or warp.

A spray apparatus was used in tempering shell at the Washington Navy Yard before 1887. It was used there in hardening one side of an armor plate in November, 1889. On October 1, 1891, an armor plate was hardened at the Bethlehem Iron Works between two sprays regulated so as to control the distortion.

The United States patents of T. J. Tresidder for spraying apparatus are dated May 24, 1892, and January 30, 1894.

became ridged and wiry, the tool marks being brought out and strongly accentuated. This was easily explained: the fibers or drawn-out particles of the metal, sheared off and bruised down by the cutting tool, were expanded and raised in heating, but the subsequent contraction in hardening being principally in the direction of their length, left the ends bristling up, marking the ridges.

It was suggested that the presence of these ridges must expedite the chilling of the metal, for, while heat was abstracted from the surface of a ridge or sides of a gash by the spray, it could only flow into the ridge from the body of the shell over the much smaller chordal area; hence its more rapid flow from the interior owing to a greater head, as it were, being maintained.

The idea of covering the surface of an armor plate, either in casting, forging, or machining, with gashes or corrugations so as to increase the area exposed to the cooling medium followed immediately; and after that came the possibility of varying the proportions and spacing of these enlargements so as to avoid distortions by obtaining a uniform cooling effect from the center to the edges of the plate. No efforts were made, however, at this time to determine the value of these ideas, and in the next three years the Harvey process was developed into practicability by the two armor making firms in this country under the immediate direction of Commander Folger, then Chief of the Bureau of Ordnance. The distortion feared was controlled by giving the plate an initial set in the opposite direction, by spraying both sides of the plate instead of one, so that by modifying the pressure on one side or the other as required, the contractions were made uniform from the faces inward and the plate retained in shape, and occasionally by rectifying under the press. The resistance of these plates so far exceeded that formerly obtained from simple steel and compound plates that the process at the start was regarded as satisfactory, no effort being made to carry the chill into a specified depth for each thickness of plate.

In 1891, Mr. Harvey patented the application of his process as a method of obtaining a decrementally hardened armor plate. It was his contention that, when the cementation was carried on at a temperature above that of molten cast iron, the effect produced was not confined to the carburization of the metal, but was entirely different from the ordinary cementation process, in that the metal was improved in quality, rendered fine grained, soft and susceptible of hardening to a degree corresponding to the height of the temperature employed in cementation. His process was therefore distinguished from the old ones employed by the manufacturers of blister steel and improvers of steel for over two hundred years, as the "high temperature cementation process." Doubtless such an improvement occurs through the volatilization of deleterious components and change of structure in inferior metal, but analyses show that this is not the case in the superior quality of metal now employed for armor in this country.

In January, 1891, a 10.5″ Schneider steel plate was Harveyed at Newark, tempered at the Washington Navy Yard, and tested at Indian Head. Its behavior was so excellent that a cementation furnace was at once erected at the Gun Factory and a number of experimental all steel and nickel steel plates of varying composition furnished by the Carnegie Steel Company were treated and compared ballistically with similar oil tempered plates. Upon the experience thus gathered, the first directions for finish Harveyed armor from regular makers was based.

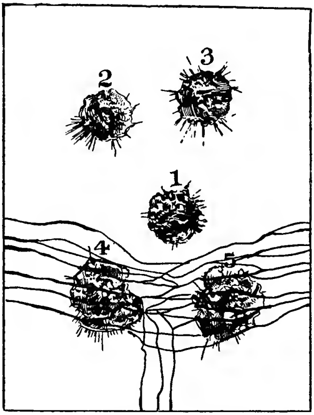
In September, 1891, three 10.5″ plates were Harveyed at the Carnegie Steel Works and two at Bethlehem; these plates were employed in comparison with oil tempered plates to determine the relative resistance of high, .40 to .53 per cent., and low, .22 to .24 per cent. carbon, all steel, nickel steel, Harveyed steel, and Harveyed nickel steel plates. The Bethlehem high carbon Harveyed nickel steel plate was by far the best. The Armor Board, however, expressed some scepticism as to the accuracy of the carbon analyses.

In July, 1892, Bethlehem made two 10.5-inch Harveyed nickel steel plates, one forged to 12.5 inches, Harveyed, and then forged to 10.5 inches; and the other Harveyed at its final thickness of 10.5 inches. The resistance of these plates was phenomenal for that time, the latter being the better of the two, through defective tempering of the first.

In October, 1892, Bethlehem manufactured a 10.5-inch curved Harveyed nickel steel plate; and in January, 1893, a 14-inch plate was made by the same firm. Upon the tests of these plates, ranging in thickness from 3 to 14 inches, the requirements of service Harvey plates were based. It is only fair to the Naval Bureau of

Ordnance to note that the entire responsibility in case of failure, as well as the expenses and program for even the last details of treatment rested at this time upon it. Early in 1893, the first contract for service Harveyed armor was made with the two great armor making firms of the United States.

The temperatures thus far employed in cementation were stated to exceed 2500° F.; it is now believed that they were as a rule under 2010° F. Since that time many difficulties have arisen and been overcome; certain of these have been referred to the Bureau as unforeseen and concomitant to the process, and therefore lying within the sphere of its responsibility, so that the process as it exists at present, while giving full credit to the armor makers, is a result to which the Bureau has continually given its assistance.



BETHLEHEM 10.5″ PLATE ATTACKED BY FIVE 8″ HOLTZER SHELLS.
Note cracks confined to Harvey surface.

So many misleading statements have been made and so many doubtful claims advanced as to the advantage of great depth of carbon penetration, while the entire process seems susceptible of so many modifications and improvements, it would be best to describe briefly the various steps of the manufacture, and more at length the theories built on those steps. For it is a fact that the theories both of cementation and hardening follow the practice but lamely and are open to numerous criticisms.

It must be understood that in describing a manufacturing process, it is necessary to draw the line sharply between the general plan or theory, which is doubtless fully protected by the patent, and the various practical details born of the manufacturer's experience and by which he makes the patent a commercial success, and the process economical and profitable.*

The information which is accessible to the public, however, in patent specifications, text-books, and the well-known methods of practical men in overcoming the difficulties to be encountered, is considerable.

The ingot from which the armor plate to be face hardened is forged must be even more carefully selected than in the case of oil tempered plates. The carbon gases in cementation seize upon and reduce the oxides found where defective welds exist, as in pipes, cold flaps and snakes, leaving thin fissures which are apt to extend and even fracture the plate in water tempering, owing to the lack of continuity of metal, breaking up and rendering the stresses irregular and unbalanced. In large ingots, especially when cast at too high a temperature and slowly cooled, the segregation of the metalloids, that accumulation of the specifically lighter and more fluid combinations of phosphorus, sulphur, carbon and silicon with iron, in the upper and central portions of the ingot where the metal last congeals, destroys its homogeneity and causes its thermal and physical characteristics to vary so much in a short distance as to practically amount to lack of continuity, especially under the extremely sudden and violent stresses of tempering. The segregation is composed of hard, brittle metal, and though its coefficient of heat expansion or contraction may not differ sufficiently from

* Thus, while methods of protecting portions of castings and forgings desired to be left soft from the action of the carburizing agents have been known as long as cementation itself, and specifically mentioned in numerous patents since 1867, a patent dated Nov. 13, 1894, was granted T. J. Tresidder for the broad claim ot leaving the edges and portions of other surfaces of plates to be cemented soft in order to permit machining after hardening. This process of stopping off the carbon was recommended by Mr. A. E. Acker, late Assistant Engineer, U. S. N., at Bethlehem, in September, 1892, and was afterwards carried out by direction of the Bureau of Ordnance. It was also employed at Homestead on the experimental plates made in September, 1891.

that of the body of the plate to cause important stresses, still it is surrounded and braced by that metal and must expand and contract with it. This would not be serious in a slowly cooled or heated plate. In the case of a wide, thick plate quickly chilled on both faces, the exterior particles set over an expanded interior and are fixed while in a state of tension. Later successive layers of the interior cool and contract, placing the exterior in a state of compression, but these inner layers being then the more mobile of the two, instead of curving the exterior so as to wholly satisfy their contraction, are themselves placed in tension, gradually released in part by the yielding of the metal. This yielding must nearly correspond, unit for unit, with the remaining extension of the surface, otherwise there would be a sliding movement of one strata on the other. The tension is undoubtedly greater toward the center of the plate, however, as the edges of the strata cool earlier, and hence in a somewhat more expanded condition. It thus appears that very nearly the same amount of combined flow of particles and elastic extension is required over each unit of each strata of a uniformly cooled plate, increasing, however, toward the middle line, where in a segregated plate the metal is most brittle and least able to respond. Segregation in the ingot may therefore cause the internal rupture of a plate in tempering, no matter how uniformly and skilfully the plate be cooled. The recent failure of an 18-inch face hardened plate representing the Indiana's side armor was entirely due to this cause, the flaw being at right angles to the line of greatest contraction.

The armor plate is forged nearly to finished dimensions and rough machined, an allowance being made in its thickness to compensate for oxidizing of the back in the cementation furnace, as well as later scaling due to the bending and tempering heats. Allowances are also made in the length and width and the angles of the sides with each other and the faces, it being generally found that all faces will become convex, opening the bounding angles. The amount and method of application of these allowances are, of course, manufacturing secrets, varying for every thickness, shape, composition and treatment of plate.

The face of the plate is then carefully scaled. Abroad many of the experimental plates have been carefully planed off. The sand blast, as employed in cleaning castings, does not seem as yet to have been utilized, although it is undoubtedly just as efficient and more economical than any of the other methods.

This scaling is very important, for not only does the film of oxide act as a non-conductor, retarding the heating of the metal, but it is necessary for the carbon to reduce this oxide before it can act in further carburizing the plate. This was well understood long before this process was applied to armor, for most of the early patentees of cementation processes and compounds indicate methods of cleansing the castings or forgings to be treated. When the scale is not removed the plate will have many soft spots.

Following the scaling, the "soft strips" or parts of the plate which are to remain untreated, in order that bolt-holes for deck or other fastenings may be made, are laid off, and the plate placed in the furnace with these parts opposed to a non-carburizing or sand bed instead of the carbon. All other parts of the face except a narrow strip about the edge, left, by direction of the Bureau, not only for finishing, but to diminish as much as possible the tendency to form edge-cracks in tempering, are cemented. This process of limiting the operation of cementation has also been known and practiced for many years.

Plates of slight curvature are bent before carburizing; those of large curvature are bent afterwards before tempering. In this later bending operation superficial cracks occasionally occur in considerable number. These will be discussed later. Whatever the shape of the plate, a bed to correspond is swept in sand on the floor of the the furnace, and upon this is placed a six-inch layer of the cementation compound, be it Harvey's or Pettino's mixture, or, for that matter, any one of a number of patented combinations which, upon being heated, produce carbon or hydrocarbon gases, and claim to obtain practically the same results. The Harvey mixture is probably nearly as cheap a mixture approaching a standard of uniformity as is at present manufactured; it is not peculiar in its action, however, and abroad other carbonaceous compounds are generally employed. It is composed of equal parts of animal and wood charcoal, the former being the expended "char" from sugar refineries. The combination is patented, the claim being that the heavier animal charcoal gives the light, powdered wood charcoal a body, enabling it to be handled without waste or the danger from explosions which result from heating a mixture of air and such combustible dust. The wood charcoal probably acts more as a dilutent and cheapener of the "char" than anything else; the mixture, however, renders up more slowly and uniformly its gases than would otherwise be the case, although it is stated that the approved method at present is to place a half-inch layer of pure animal charcoal next the plate. A too rapid introduction of the carbon destroys the grain and strength of the metal, making it resemble pig iron. The great thickness of the layer is rendered necessary by the volume of gases required to be generated in the long process, which exhausts the material, as well as the importance of gradually obtaining and maintaining a high and equable temperature. The great thickness of non-conducting material between the flues and the plate makes it a long operation to obtain the desired temperature, but once reached, sudden fluctuations are impossible.

The plate being placed in the furnace, its sides and back are covered with sand or loam, rammed down, then a layer of fire-brick, the furnace cover is placed in position and the ends walled up. At the Carnegie Steel Works, where natural gas is used, a platform car forms the bottom and sides of the furnace, and this being charged is run into its housing and the fires started.

There are many varieties of cementation furnaces, each claiming special advantages, the important feature of all being the obtaining of a uniform and high temperature by surrounding the brick or fire-clay flask with furnaces and flues conveying the products of combustion towards the stack.

The furnaces using natural gas and oil are probably the most costly, on account of the numerous valves required, but once erected they are the most convenient and permit a nice adjustment and variation of the temperature. They are doubtless also more rapid in their action if desired.

The original furnaces employed by Mr. Harvey were very slightly different from the old-fashioned cementation furnaces; they used coal; afterward oil burners were introduced. That erected at the Naval Gun Factory in the winter of 1890–'91 used soft coal, and those built at Bethlehem in 1891 are similar. Two regenerative furnaces at Homestead were temporarily converted into cementation furnaces in the summer of 1891, but their present splendid plant of twelve gas furnaces was built in 1893, and are entirely different from and regarded as superior to the old type of furnaces.

The difficulties to be guarded against and overcome in working these furnaces, no matter what the fuel, are very great. The high temperature and the great weight and size of the charge, as well as the long time required, prevent the use of iron flasks such as are used in cementing small articles, for even should the white-hot iron fail to break down under the weight, it would quickly oxidize and become unserviceable. Fire-brick or other forms of intractible material must, therefore, be used for the lining of flues and flasks. These expand largely and become extremely tender at a high temperature, introducing other dangers from settling or collapsing, by means of which air may gain access to the carbonaceous material, which is then quickly consumed and the metal fused. To raise an armor plate weighing between thirty and forty tons to the temperature of from 2230° F. to 2500° F., required by the Harvey process, and keep it there for weeks, supported on brittle fire-brick, is to run a serious risk.

These considerations, and the great expense of the process as at present applied, led the writer to investigate the practicability of reducing the temperature and time of cementation at one and the same time. The problem seemed difficult, especially as it was claimed by some that the process, even when carried out with the utmost skill and patience, was hardly a controllable one, and that a variety of results from apparently identical conditions might always be expected. The project of increasing the cooling surface of an armor plate in tempering, by corrugating or gashing its surface, was recalled, and the feasibility of employing these enlargements of the surface at an earlier time to expedite the cementation seemed unquestionable. This germ of an idea quickly expanded and the proposition became—to cover the face of an armor plate with a series of gashes, or pockets, or corrugations, by means of which the area, over which the carbon or other cementing material could penetrate, might be multiplied, and an equal percentage of carbon introcuced into the superficial layer in a proportionately less time than in the case of a plane surface. These enlargements to be so proportioned as to permit the maximum percentage of carbon to extend in to a greater or less depth according to the thickness of the plate, thence shading off into the body of the plate so as to prevent a too sudden transition of grain and extensibility along a single plane—that of the inner limit of the chilled surface—in order to avoid the flaking off of this surface under impact.

The impracticability of rolling or forging such a surface down after cementation without leaving it covered with defective welds, cracks, or seams, was apparent from the first. The writer had, however, been much impressed by the numerous severe tests of Gruson chilled iron armor, from 1882 to 1890, in which it was shown that cracks confined to the chilled surface in no way reduced the resistance, and never originated, extended, or gave direction to the cracks due solely to impact. The success of Sir Joseph Whitworth's experimental plate, in which his proposition "to prevent cracks by manufacturing them" was exemplified, seemed also to indicate that such superficial defects, far from weakening the plate would prevent flaking and the extension of cracks. This conclusion was at this time supported by the excellent behavior of a face hardened plate, the surface of which was covered by a network of cracks formed in rectifying, and soon after by that of three other plates tested to destruction. In fact, on one of these plates the cracked surface was more resisting than the sound, which was to be expected, as the chill was able to enter more deeply where the edges of the cracks permitted deeper contact of the cooling agent.

Another feature of the proposition is that as the various ridges and corrugations would attain the desired temperature far earlier than the flat surface of the plate; this would reduce the time of the process materially, especially as it would not be attempted to obtain the peculiar advantages claimed from the use of a high temperature, as in the Harvey process, at all. The intention being merely to introduce a certain percentage of carbon into the superficial layers of the plate in the same manner, and at the same temperature that cementation has been carried on for many years past.

Such a process would be extremely useful when applied to rectangular blocks for the sea faces of forts, turrets and floating defenses having no room for a slope. These blocks would not necessarily be forged and shaped to the extent and accuracy of dimension required for ship armor. There are many existing fortifications of little defensive strength on account of the exposure of their masonry faces to attack, these could be protected at comparatively little expense by deeply cemented face hardened armor. There are also locations such as Roma shoals, Race rocks, etc., where turrets will be required protected by armor of this description.

It is evident that any new process which at one and the same time permits practically the same results to be obtained at a much lower temperature and in less than one-half of the time now required will be of great value, as not only will the output of a furnace be more than doubled and the cost of fuel and labor per ton of output less than one-half, but the life of the furnace will be much longer and the time, labor, and materials expended in repairs largely reduced.

The advantages claimed for the proposed process are, however, by no means confined to the reduction of the cost of manufacture. It is firmly believed that a more resisting armor can be made in this manner than is at present possible by any other process.

It is also proposed to expedite, in a measure, the heating of the charge by placing numerous pins of good conducting material in the bed of the furnace. Fluctuations in temperature will be hardly more possible than at present, while time will be saved by heating the non-conducting mass as a whole rather than from one surface.

When thin plates are cemented, a number are placed in the furnace face to face, with a layer of the carburizing material between. (This plan was first employed at the Bethlehem Iron Works early in 1893.) Embedded in this are wrought iron tubes, extending from end to end of the furnace, and in these are placed the test rods, which can be withdrawn from time to time for inspection, without admitting air to the interior. Their color, from end to end, indicates the uniformity as well as degree of temperature of different parts of the charge, and the various flues are dampened or burners and fires regulated accordingly.

When the desired temperature is reached, determined either by the color of the bars or by means of a pyrometer employed at one of the tube openings, the fires are regulated to maintain that temperature for a greater or less time, according to the thickness of the plates.

Considerable time is lost in gradually cooling the charge, as it cannot be exposed to the air at a high temperature, as oxidation and scaling would result, the plate might also be chilled or air hardened. Especially is this the case with nickel steel, the nickel seeming to render more sensitive and to increase the hardening capacity of the carbon, so that the difference of the effect of cooling in the air of a cold, moist climate as that of Sheffield, England, and the dryer, warmer atmosphere of Pittsburg or Bethlehem might cause the difficulty said to be found abroad in machining unhardened carburized nickel steel, and which our armor makers have been able in a great measure to avoid. The plates are then air annealed from a cherry red in order to break up the large crystals in the cemented face.

After carburizing, analyses are made at various depths from each end of the plate, to determine the percentage and depth of carburization. The plate is then machined and bent to such shape and dimensions as experience indicates will most nearly result in those desired after hardening. This machining, as a rule, includes all work done on the hard face, although an electric annealing apparatus has lately been devised, by means of which the hardened metal may be softened locally when desired.

The plate is then carefully heated to the temperature required for hardening, the hardness and depth of chill increasing, within a certain limit, with the height of temperature to which the plate is heated. It will be seen at once, the higher the temperature the more plastic the metal and the greater the distortion. The lower the temperature can be kept and still produce a hard surface the better for the manufacturer, as the subsequent rectification will be less difficult.

The plate being heated to the desired temperature is placed upon the tempering stand, and a powerful spray from a large number of small, evenly spaced jets is forced upon both sides of it. This spray is modified from time to time as required to keep the plate in shape. After the plate's exterior has been thoroughly chilled, it is lifted into the oil bath and left there until cold. Occasionally a plate will be found that will not respond to treatment, becoming distorted, in which case the process is repeated. In so doing, of course, there may be a loss from scale as well as the oxidation of the superficial carbon. If the plate is but slightly out of shape it may be bent cold under the press; this, however, frequently causes the hard face to crack in a most alarming manner. The effect of these cracks, however, on the ballistic resistance is, as has been stated, of no consequence.

Finally, the plate has its bolt holes tapped in the back and is finish-machined, it sometimes being necessary to employ an emery wheel, or electric annealing, at the hardened edges to obtain the desired perfection of joints and butts.

A great difficulty in the treatment at first was the oxidation on the back of the plate ; there is no loss from the carburized face unless it is overheated. In England a clayey cement has been used with good results. At St. Chamond it has been the custom to decarburize the back of the plate in order to render it more ductile while carburizing the face. It is doubtful whether any benefit is derived from this, however, unless the plate later receives some forging. It is also said that plates are very much improved after cementation by a careful annealing in carbon. Doubtless, if armor plates are machined after cementation, a thorough annealing before hardening would remove any stresses liberated by the removal of the surface metal, and which would tend to complicate and render those introduced in tempering unmanageable, otherwise the annealing seems expensive and unnecessary except, of course, when the plates are removed from the cementation furnace at a temperature sufficiently high to be air hardened.

The effect of water hardening a face hardened plate varies not only with the depth of the strata of metal but with its composition. Careful analyses show that in good plates the normal carbon may be found at a depth of of 1.25″, but that the effect of water tempering will be found to reach to the heart, increasing the strength and toughness to a remarkable degree even though the normal carbon may not exceed 25 per cent. Vickers' claim to obtain this effect at a depth of seven inches inches in a ten and one-half inch plate is fully justified by facts.

SECTION II.

CEMENTATION.

The practical features of the manufacturing of modern face hardened armor having been discussed, it will be interesting to note the present state of the theories of the two important steps, *cementation* and *hardening*.

The art of cementation was practiced by the ancients. Tubal-Cain made steel by surrounding iron with charcoal and exposing it to the long continued action of a comparatively low and slowly penetrating heat. Later, furnaces were constructed which could be sealed so as to exclude the air to avoid melting or oxidizing the charge, while the higher temperature employed permitted the carburization to be carried on rapidly.

In Landrin's Treatise on Steel is given an interesting account of experiments made by Réaumur in 1722 to determine the best compound with which to convert iron into steel. For this purpose, Réaumur used not only the materials commonly employed for case hardening in France, but specially prepared and exploited mixtures, as well as certain formulas said to have been obtained in Germany. Iron bars were heated in crucibles with various inert substances, such as sand, potter's clay, ashes, glass and lime, "the only apparent change being a loss of fibre in fibrous iron and a diminution of thickness of lamellae in laminated iron."

Various salts and alkalies were also tried, without difference of effect, in combination with these inert substances. Oils, when mixed with sand or clay, burned off and were lost before the metal was sufficiently heated. A combination of oils and alkaline salts, as soap, or soot with charred horn and leather, however, was found to transform the iron into steel.

"Charcoal, soot, or old burned leather, of themselves, produced a fine, hard steel, difficult to work, and even after forging full of flaws and cracks. Pit coal, powdered and sifted, had a very rapid effect, diminishing the volume and corroding the metal which became hard and fine, but harsh steel."

His conclusion was that powerful alkalies helped the conversion, but the resultant steel was difficult to work, full of flaws and incapable of welding or drawing out. A peculiar effect occasionally produced by certain salts, as sal ammoniac, green vitriol, etc., was that the steel was not lasting, for when forged and hardened once, it had a fine grain, but forged and hardened a second time, it had scarcely any grain. Finally, common sea salt was regarded as the most suitable for the conversion of iron into a fine, hard steel, easily worked and lasting.

"The composition which answered the best for converting iron into a very fine and hard steel is 2 parts soot, 1 part powdered charcoal, 1 part ashes, and $\frac{3}{4}$ part of common salt.

"The formula should be varied to suit the iron. The greater the percentage of oily matter, found mostly in the soot and charcoal, the more rapid the process, though the steel is apt to be flawy and hard to work. Increasing the percentage of ashes slows the operation and diminishes the deleterious effects; the minute proportion of alkali in the ashes acting as a carrier, the earthy matter as a moderator. The salt is not absolutely essential, but it hastens the operation, adding to the fineness and hardness of the steel as well as largely reducing the amount of composition required. Increasing the amount of salt increased the flaws. In converting irons tending to become harsh, 1 part of lime or calcined bones might be added with the result that a steel otherwise impossible to forge could be easily worked." One-eighth part of lime added diminished the blisters which later gave a name to this kind of steel.

So much for the published knowledge of the process of cementing steel 175 years ago. Since that time a large number of processes have been advocated, and it will be interesting to note the more or less reliable claims of some of these.

In 1859, a Mr. Johnson patented "a cementation compound of equal parts of quick-lime, bone dust, and wood charcoal, which, after an intimate mixture, was exposed to dry weather for several days." He explains "that this enabled the lime to absorb carbonic acid from the atmosphere, by which means he obtained the necessary carbon in the purest and most convenient form." He found that Swedish or Danemora iron "containing so much P as to give an odor of it when twisted at a red heat" is cemented much more rapidly than other irons. "A bar of such iron $\frac{3}{16}''$ thick being converted completely in two hours, while a similar bar of English iron was converted but $\frac{1}{16}''$ deep in the same time." Believing that P was essential, he added bone dust on account of the basic phosphate contained, which either enters into combination with the iron or, by more or less doubtful catalytic action, aids in accomplishing the same result. This mixture could be used again and again after each operation by exposing it to the atmosphere so as to take up CO_2, and adding a small amount of lime.

The fact is, of course, the highly oxidized lime probably took up moisture by selection of H from the air as well as C from the carbon present in the charcoal.

The presence of P was regarded as important by the late Mr. Harvey, who found that the operation was rendered much slower and less effective without P, and that the bone charcoal was therefore the most important ingredient in his mixture. As, however, the basic phosphate is not reduced at the usual temperature of cementation, its effect can hardly be due to the absorption of P by the metal.*

In 1861, Mr. Weston explained the action of a mixture of cyanide of potash and charcoal as follows: "The cyanide is decomposed by heat into cyanogen gas and potassium, and the first upon contact with the metal is broken up into C and N, the C uniting with the iron while the N unites with the charcoal, and in the presence of the potassium forms another portion of potassium cyanide. Any compound of cyanogen with an alkaline metal may be used."

It has been asserted by M. Frémy that cementation cannot take place without nitrogen. This is not so, cold iron buried in powdered charcoal absorbs carbon even without the aid of heat. Nitrogen is merely a convenient gaseous carrier. Under the effect of heat it combines with carbon present, forming the easily decomposed cyanogen gas which penetrates the expanded pores of the metal and weakly gives up its carbon to the iron. If hydrogen is present, a small proportion of H_4N is formed, which accounts for the ammonia gas found accumulated in the shrinkage cavities of castings or often perceptible when metal is fractured.

In 1868, a Mr. Sheehan places in the bottom of his retort fragments of limestone covered with a perforated plate, and above that a carbonaceous mixture of 200 parts of charcoal saturated with water, 30 parts of muriate of soda, 12 parts of sal soda, 5 parts each of black rosin and black oxide of manganese. "On heating, the carbon is expelled from the limestone and unites with the oxygen and carbonaceeus ingredients above to convert the iron."

In 1875, M. Eyqueur employed peat with 1½ per cent. ammoniacal salt, preferably hydrochlorate. He states that "the carburization takes place under the simultaneous action of ammoniacal

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* It is the writer's opinion that P acts as a reducer of CO; it is well known that the value of P in phosphor and manganese bronze is due to its reduction of CuO.

and carbureted hydrogen gases, the iron passing to a state of zoto carburet and the rapidity depending upon the nascent condition of the gases."

In 1891, Brown's compound was patented; it is composed of 87 per cent. pure carbon, 8 per cent. calcined lime, 4 per cent. soda ash, and ½ per cent. each of tungstic acid and sal ammoniac. The action is said to be that "the soda ash frees the metal of oxygen, opening the pores or intermolecular spaces, while the calcined lime eliminates the oxygen set free or remaining in the retort. The bone carbon then commences to throw off its carbon, and with the help of the ammoniacal gas generated from the sal ammoniac a pure cyanogen gas is generated which permeates the metal, carrying with it the free tungstic acid which tends to give the metal greater hardness."

In 1893, a Mr. Hunter patented a compound of 25 parts muriatic acid, 16 of salt, 32 of chloride of lime, 32 of carbon. The action claimed is that "hypochlorous acid, HClO, generated in contact with the heated carbon and metal by which it is decomposed into Cl, O, and H, the oxygen and hydrogen taking up carbon and with it penetrating the iron, the operation being facilitated by the presence of the Cl. The salt may be omitted but is important when the metal contains considerable silicon."

In MacIntosh's process, wrought iron bars were suspended in a furnace, the walls of which are highly heated; de-sulphurized coal gas is then passed through. The process was very efficacious, though expensive.

There are also many gaseous methods of cementing steel, that of Schneider, for example, in which a highly heated retort contains two armor plates placed face to face and separated by a frame work at the edges, thus forming a chamber into which hydrocarbon gas at a constant pressure is introduced at a high temperature. There are also numerous other processes of combining the cementation and improvement of iron and steel, by heating in the presence of carbonaceous mixtures. The explanations of very few, however, are satisfactory, and the claims of many others are based on assumptions which are far from being generally accepted as scientific facts.

The processes may be divided into groups, as they employ gaseous and solid or liquid compounds. Probably all are really gaseous in action, for it is difficult otherwise to explain the transfer of solid carbon from the distant and large sized lumps of charcoal employed in the old cementation process. It has also been found in cementing armor that the carbon gases at times penetrate considerable thicknesses of sand and impregnate the steel beneath.

The movement and commingling of atoms of many different substances when closely associated is known to occur under the influence of heat. The well-known experiment of Sir Lowthian Bell in which smoothed discs of cast iron of 3.25 per cent. and wrought iron of .04 per cent. carbon, were tightly bolted together and heated in a furnace for one month with the result that the cast iron lost 1.07 per cent. and the wrought iron gained .348 per cent. carbon, would seem to indicate at first that the carbon gained, under the influence of heat and pressure, something of the freedom of a gas. Still the enormous volume of elemental gases contained by the cast metal, renders such a conclusion unnecessary. This is also the case with the old method of cementation, in which a heated bar was stirred in molten highly carburized cast iron and then quenched; or in the comparatively late process, in which iron is cast directly upon the face of an iron or low steel plate and then exposed to severe heat for a long period of time with the result that the carbon gradually becomes so distributed as to destroy the plane of demarkation.

This interchange of atoms is not confined to carbon alone, for it is noted in the Journal of the Iron and Steel Institute, Vol. I., 1889, p. 368, that the welding of iron to nickel brought about the transposition of atoms. For after dissolving off the iron back it was found that the percentage of iron in the nickel had increased from 0.9 per cent. in the original to 3 per cent., the normal percentage of iron being found only at a depth of .45 of the thickness of the nickel. Iron is stated to be volatile at a medium red heat, for when alternate sheets of nickel and iron are heated to redness for some time, the former increases in weight through absorption of iron, a true alloy of iron and nickel forming at the surface of the latter. Whether the nickel has a special influence, or whether this volatilization is going on at all times and in all directions from heated iron is not stated. It would therefore seem that the iron has the power to meet the carbon half way, both being volatilized and possessing affinities, when, of course, the formation of a definite carbide would naturally follow.

In Sir Lowthian Bell's Principles of the Manufacture of Iron and Steel, he demonstrates the readiness with which carbon is deposited at and up to a red heat in iron sponge from carbonic oxide. In the Journal of the Iron and Steel Institute, Vol. II., 1891, he also notes that nodules of iron oxide in the bricks lining the flue along which the gases for a blast furnace were conducted caused the deposition of carbon from carbonic oxide which penetrated the bricks, thus cracking them apart. Mr. Snelus also found that red brick in flues took up enormous quantities of carbon from the gases, one brick containing as much as 45 per cent. of carbon.

Sir Frederick Abel also stated before the Iron and Steel Institute in 1892: "The carbon impregnation of an iron ore takes place at as low a temperature as de-oxidation, which in Cleveland ore occurs between 392° F. and 410° F. At that temperature freshly reduced spongy iron reduces carbon from carbonic oxide to an extent corresponding to 20 to 24 per cent. of its weight, but as the temperature approaches a red heat, the deposition of carbon diminishes considerably in amount. The increased effect of a nascent condition of both iron and carbon is here apparent. Experiments also showed that nickel, and to a smaller extent cobalt, suffer reduction from their oxides (below red heat) with deposition of carbon."

In the Encyclopædia Brittannica is found "The process of cementation is that of the occlusion in the iron of CO formed by the combination of C with the air in the charcoal. This is then decomposed by the iron into C and an iron oxide, which is then reduced by a second portion of CO.

Thus (1), $Fe_x O_y + {}_yCO = Fe_x + YCO_2$,
and (2), $Fe_x + YCO = {}_yC + Fe_xO_y$.

The CO_2 penetrates less readily through the metal than the CO, and in doing so forms blisters." This seems hardly probable. It is much more probable that the CO_2 having satisfied its affinity is the only gas left in evidence in the presence of the oxidized scale or blister.

Judging from the statements made by Sir Lowthian Bell and Sir Fred. Abel, the formulas given in the Encyclopædia are correct for low temperatures; Sir Fred. Abel states, however, that as the temperature approaches a red heat, the deposition of carbon largely diminishes.

As the temperature at which carbon combines with iron in the carbide Fe_3C lies at about 1200° F., it would appear that above that temperature the carbon must be associated with the iron in another form, perhaps merely deposited, while the carrying gas, be it N in cyanogen, O in the oxides, or H in the hydrocarbons, joins some more volatile substance present, or escapes in the elemental condition.

At the highest temperature it is probable that the following formulas would be more nearly correct:

$$(1) \qquad 2Fe_x + YCO = Fe_xOY + Fe_xC_y,$$
$$(2) \qquad Fe_xO_y + YCO = Fe_x + YCO_2.$$

From this it would appear that when the O present is exhausted the process must stop, a conclusion which agrees with the practice of renewing exhausted compounds by aeration.

The iron exposed in the pores has a capacity as Fe_3C for one-fourteenth its weight of C. In the entire mass only 63 per cent. of that has been found of combined carbon.

The changes in volume of the metal in solidifying and cooling are very irregular; thus, steel on congealing expands, on cooling contracts, but in the latter case neither regularly nor continuously. There are three points of recalescence or evolution of heat accompanied by an increase of volume in cooling from a temperature slightly over 1800° F. These, according to Mr. Osmond (see Journal of the Iron and Steel Institute, 1890, Vol. I.), are: 1st. A slight evolution of heat at about 1562° F. 2d. A very faint ovolution of heat at about 1382° F. 3d. A point, absent in mild steels but strongly marked in high carbon steels, at 1200° F. These "critical points" and their meaning are discussed in a valuable paper on the Physical Influence of Elements on Iron, by Prof. J. O. Arnold, in the Journal of the Iron and Steel Institute, 1894, Vol. I. The highest critical point is considered to be due to chemical changes accompanying the evolution of hydrogen. That at 1380° F. is regarded as physical, due to the passage from a plastic to a crystalline condition; and the lowest is due to the combination of iron and carbon into the definite carbide Fe_3C.

Undoubtedly the process of cementation is affected by the various conditions of expansion and structure of the metal found between the normal temperature and the melting point. There are reasons for believing, however, that no advantage will be obtained by exceeding 1832° F., all of these phenomena being manifested below that temperature. Above it, the metal is regarded as contracting to the melting point, the pores are diminished in size and the carbonizing gas has become extremely attenuated. Doubtless the greater molecular activity at this high temperature will permit a considerably greater absorption of carbon in the surface layer with an abrupt reduction to the normal percentage. The time required to reach and cool down from this temperature, the cost of fuel, together with the greater risk and uncertainty, render the high temperature less satisfactory than another method which may be proposed. That is, by corrugating the surface or covering it with shallow pockets, the walls of which being thin will be affected much earlier and at a lower temperature than the massive body of the plate. Later these irregularities may be forged down if desired.

Percy says that pure carbon will not cement, and that it will only continue to combine while gaseous matters are given off. It is evident, however, judging from the most successful and rapid-carburizing agents, that the process of cementation is best carried on by a compound which under heat influence liberates an easily decomposed carbon gas. This, penetrating the pores of the metal in a nascent condition, combines readily with it, especially if the iron be freshly reduced. This is known to be the case with hydrocarbon gases, and cyanogen, and is believed to be the case with carbonic oxide and dioxide. Any material which when heated would continuously render up these gases would enable cementation to be carried on. Above the temperature of 1200° F. this process is probably effected, in the case of carbon gases, by the deposition of carbon and the formation of an iron oxide. The latter may be reduced by CO with the formation of CO_2 which passes on into the metal repeating the operation, the smaller volume of C, and the less degree of completeness of each succeeding operation, causing a gradual diminution of the carbon deposited.

It follows, therefore, that if a larger surface of metal is exposed to the action of the gases, as by gashing or scarifying the surface of the plate, the process will be greatly expedited, the volume of gas directly in contact with the plate being not only much greater but at work at the same time over the entire depth of metal to be treated.

Hammered iron is said to be more rapidly cemented than rolled iron perhaps on account of the rough scale left in the latter case. It is also said that the porosity of steel is generally in an inverse ratio to its tensile strength; this is not always so, still it is very certain that the low tensile requirement before treatment makes possible the employment of a steel which takes up the carbon very readily.

The process of cementation also reduces the amount of sulphur present; according to Boussingault, one-half at least is volatilized in the form of a carbon sulphide. This doubtless refers to inferior grades. It would seem that by the disengagement of volatile matters associated with the iron, the latter would be left in a receptive condition, favorable to rapid cementation.

The heavier the charge the longer must it be maintained at the temperature of cementation to obtain the same depth and percentage of carbonization; in fact, the amount of carburization in equal times varies approximately inversely as the volumes of the charges.

The temperatures at which the cementation is carried on varies greatly; that employed in the manufacture of blister steel is about 2100° F., that for the Harvey process, "above the temperature of molten cast iron," must exceed 2228° F. The desired effects, however, have been produced in about the same time at as low a temperature as 1750° F., and many excellent armor plates have been cemented at a temperature never reaching 2000° F. In fact, little if any of the excellent face hardened armor manufactured at Bethlehem has been cemented at a temperature above that of molten cast iron. At Carnegie's the temperature has also been reduced, it is believed with benefit to the metal. That found most satisfactory abroad is said to be 2000°–2050° F., which is below the melting point of even white cast iron. It is probable that with greater experience European armor makers will reduce the temperature.

The time required to reach the required temperature varies; a plate 6.4″ thick required 4 days, and the temperature was maintained 6½ days, after which it was allowed to fall. In the case of a 9.5″ plate, these times were respectively 6 and 8 days. These plates were of excellent quality.

The percentage of carbon required on the surface by the Bureau of Ordnance is that which will not through its regular diminution reduce the depth of chill given by the hardening process, limited and regulated as it is to prevent distortion.

SECTION III.

HARDENING.

Henry Marion Howe explains the effect of hardening in improving the strength and toughness of steel as follows :

"Dissimilar rates of contraction produce a kneading effect. There must be between the various layers considerable kneading pressure and rubbing ; and as this, in kneading dough or putty, through compression ; in forging, through compression and tension ; in molasses candy, through tension, appears to increase the intermolecular cohesion, so we may ascribe to this feature of hardening the increased strength and toughness." . . . "The hardness proper is due to the maintainance of the chemical condition existing at a red heat, but the changes in tensile strength and ductility to a joint effect of chemical and physical origin. Annealing may obliterate all the effects of sudden cooling except that due to the kneading of the metal, which resembles forging and increases the strength, so that by proper management we may increase both tensile strength and ductility by tempering and annealing."

The Société de Châtillon et Commentry claim to have established the fact that soft steels simply cast, after being lead tempered, have the properties of forged steel. The process, however, requires great knowledge of the conditions for making the steel, the temperatures to maintain varying very sensibly with the nature of the metal.

M. Pourcel, of the Terre Noire Works, has also long contended that all the benefit of forging can be obtained on large castings by a proper course of treatment.

It is the idea of Frederick Siemens in tempering glass that by uniformly cooling every part of the body of the glass, no matter how rapidly this is done, the contraction of the mass—the cessation of molecular movement—is uniform and there are no strains introduced. Granted that no *irregular* strains would be introduced, such as snap a tempered steel shell, still there must be minute balanced couples of stresses which hold the molecules together with greater tenacity than in the case of ordinary glass.

If these couples making, perhaps, an enormous aggregate, are irregularly disseminated among the weaker couples of ordinary glass molecules, then those stresses tend to develop which so frequently cause the spontaneous fracture of tempered articles. Such a condition must result when steel is heated too rapidly or irregularly. The carbide is not uniformly disseminated, the metal is not uniformly expanded, and the result of rapid cooling cannot help but accentuate these irregularities until perhaps the surface is covered with cracks or the metal actually flies to pieces.

It is difficult to conceive a rearrangement of molecules causing a body to occupy a larger volume according to the degree of hardness when chilled than when slowly cooled, without the introduction of stresses. It seems probable that the unsatisfied affinities of the carbon for the iron, existing, however, only during a very brief period of the cooling, places the whole body in a state of constraint. There is strong doubt that at any subsequent period of cooling these stresses are released by a conformity of the molecules, as each instant their movements become more difficult; besides a shrinkage of the mass would hardly satisfy a chemical affinity.

Professor S. P. Langley has demonstrated that it is possible to somewhat harden steel from a temperature no higher than that of boiling water, which would indicate the continuance of a very powerful affinity, as the movement of the atoms must then be extremely difficult. Similarly it is known that severely hardened tools have been found with the lapse of time to have become tougher and less brittle hard.

The hardening tendency is said to be proportional: (1) to the amount of carbon, hence the volume of chemical attraction; (2) to the rapidity of cooling, hence the proportion of that attraction unsatisfied; (3) the height and duration of the temperature of hardening, hence the amount of carbon dissociated from the carbide and disseminated among the grains of iron.

At a temperature above 1200° F. the carbon existing in the form of a carbide of iron, irregularly coagulated in the steel, commences to disintegrate and dissolve itself through the mass of metal. This movement is undoubtedly the more difficult the less the metal is expanded and heated above the temperature of chemical combination. The more slowly the metal is heated to the higher temperature, the tougher it becomes without loss of hardness; this toughness increasing with the length of time of exposure to that temperature. The higher the temperature of hardening, within limits, the deeper and stronger the effect of the chill. Upon cooling the metal slowly, however, the carbon again seizes the iron and with the aid of the forces of chemical affinity and incipient crystallization again becomes segregated.

The range of maximum hardening effect has, therefore, for its upper limit that temperature at which the heat dilation first overcomes the chemical attraction, and for its lower limit that point where the chemical attraction is no longer able to move the sluggish atoms.

"If the steel be long exposed to a high temperature, say a light red or orange, it assumes a coarsely crystalline structure which it retains in cooling, and its toughness and strength are greatly impaired. The more slowly the steel is cooled within reasonable limits the softer and tougher it becomes, the major part of the effect being produced in cooling from a cherry red to scarcely visible red.

"The best general results in hardening are produced by quenching from the lowest temperature which will produce the desired result. The more rapid the cooling the harder the steel and, up to a certain point, the greater the tensile strength, but if very violent the strength may be diminished. The lower the C the more rapid should be the cooling to give the greatest advantage."—*Howe.*

The rapidity of cooling, in turn, depends upon the cooling medium. "In general, the greater the specific gravity, specific heat, mobility, latent heat of gasification, coefficient of expansion, and thermal conductivity, and the lower the boiling point and the initial temperature of the cooling media, the more suddenly will the immersed metal cool."—*Greenwood.*

The thicker the piece the greater the chill required to produce the same hardness.

Experiments show clearly that the transmission per degree of difference between hot gases on one side and water on the other side of a plate was directly proportional to that difference, the total transmission therefore being proportional to the square of the difference. The more smoothly machined the faces were the less efficient in transmitting heat. This might be expected, as the rougher they are the larger the heat transmitting area.

Caron concludes, after experimenting with mercury, water containing different salts, covered with oil, or containing syrupy or mucilagious matters, that the *degree of hardness* and other effects appear to be inversely proportional to the square of the time of cooling the metal.

Chernoff says, with regard to cooling in water, the conductivity of hot metals is very small, and that although the external visible parts soon show the desired fall of temperature, yet the central portions remain very much hotter. In fact, while the specific heat increases with the temperature, the conductivity decreases, iron losing nearly 25 per cent. between 0° C. and 100° C. This evidently limits the depth of "chill" obtained even with the most violent treatment, no matter what the composition of the plate.

The fact that in a thin plate there is a smaller accumulation of heat to be dissipated in chilling than in a thick one, indicates at once that, as the hardening effect is due to the rapidity with which the temperature is caused to fall from redness to 450° F., and that as the specific conductivity of the metal diminishes as it becomes hotter, the heat transmitted between two points, while varying nearly directly as the difference of têmperature, is less and less for that difference as the interior of the plate is approached. At the same time the outer layer parts with its heat with a rapidity nearly due to a flow from a mean point between redness and 450° F. to water of 40° F. This is, of course, hardly the truth, the heat of the surface being dissipated mainly in the specific heat of the spray and the latent heat of its vaporization, rather than by conduction. Nevertheless, the exterior layer being reduced thereby, almost instantly, to a certain temperature t, the second layer parts with its heat with a decreasing rate as its temperature falls and approximates that of the first. The result is a rapidly decreasing rate of fall of temperature as the surface is receded from. This rate decreases almost as rapidly for another reason, that is, that the specific heat of the hot metal is considerably greater than that at the surface, so that even if the flow of heat was equal at the two points, the interior would require a proportionally longer time to fall a degree than the exterior. So long, therefore, as the claim is upheld that hardening is due entirely to the carbon in the steel, and the rapidity of the fall of its temperature, there will be a point quickly reached beyond which the metal cannot be chilled; and so long as certain elements, as chromium and nickel, are believed to have no power in themselves of hardening or increasing the conductivity of the metal, their effect in delaying the change from hardening to cement carbon cannot be very important, so far as increasing the depth of the chill is concerned.

The advantages to be gained by breaking up the surface to be hardened by gashes and ridges are manifest from the above. The comparatively small volume of metal in the ridges may be given the same hardness with a less severe chill than the unbroken surface of the plate. This means that the quenching temperature may be lowered and the distortion diminished. At the same time, the fissures will permit the body of the plate to be more rapidly cooled, thus increasing its toughness.

The phrase "decremental hardness," as applied to face hardened armor is very misleading; so far as hardness pure and simple is an advantage to such armor it is usually confined to a comparatively thin and uniform layer, below which the metal exists in a decrementally toughened, rather than hardened, state. At the same time, hardness with its consequent brittleness is to be avoided at a great depth, as the plate will tend to split.

It is known that there is no difference whatever, under the elastic limit, between the extension, for equal stress in equal lengths, of soft and tempered steel. Mr. Edmonds, of the Woolwich Gun Factory, stated in 1891 before the Iron and Steel Institute that the modulus of elasticity is scarcely altered by oil-hardening. That is, for example, a nickel steel armor plate whose elastic limit in the untempered condition is 46,000 lbs., and when tempered 66,000 lbs., would stretch equal amounts for equal stress in each condition. In the first case, however, permanent deformation would begin with a stress of 46,000 lbs., and in the second with 66,000 lbs.

Mr. J. G. Dagron has also found by a series of experiments that the permissible compression load on iron and steel columns varies, not as the strength of the material, but as its modulus of elasticity.

It is in fact the modulus of elasticity which chiefly concerns us, as the superficial hardness given highly carbonized metal by water-quenching is very different from that obtained in oil-tempering, and largely increases the modulus of elasticity. Steel has been obtained having a tensile strength of 400,000 lbs. per square inch with practically no flexibility and very little elongation. The enormously increased modulus of this metal over that which it possesses in the annealed condition, indicates in a fair degree its increased resistance to compression, abrasion, and puncturing, in fact its hardness.

At a certain point beneath the surface of a face-hardened plate, depending upon the severity of the chill and the percentage of carbon, the original modulus may be found. The elastic limit and the tensile strength below this point have, of course, been raised, the former proportionately more than the latter, but the extension per unit of stress under the elastic limit remains practically uniform to the back of the plate. Towards the face, however, the modulus increases, at what rate or to what extent it is impossible to say. It is merely known that the hardness does not in every instance correspond with the depth of the chill. By the "chill" being understood the fine, bright, and uniformly grained surface layer, sharply divided in appearance from the heterogeneous interior of the plate. The thickness of this layer varies with the composition and treatment of the steel from a barely perceptible film to about 0.6″. Although the metal below the chill may be very hard, its uniformity in appearance leads to the supposition that the change of modulus does not occur within it, but rather with the change in character of the metal at the border of the chill, thence increasing towards the face. This assumption is supported by the fact that flaking, due to the unequal elastic extensions of adjacent layers, occurs principally at this depth, seldom or never below it, and often outside of it. Doubtless the difference in the structure of the metal may account for the flaking, as well as the change of the modulus; that they are coincident, however, seems unmistakeable.

The existence of flaking, in that it indicates the sudden release of stresses exerted in resistance to shot penetration over a considerable area is a serious defect. The chill, however, is not always so sharply divided from the metal below; in fact, certain

Harveyed plates have not flaked at all, the metal around the impact chipping out in wedge-shaped pieces, showing a more gradual diminution of hardness; such plates crack. The sharp line of demarcation of the chill is perhaps due in some cases to checking the spray from time to time to permit rectification in hardening. Such a procedure would tend to cause laminations of varying hardness, more or less distinct as the rapidity of cooling is greater and the temperature higher, from which the plate is cooled.

The action of the hardened face under impact is to bind together the tougher elastic particles beneath, opposing the extension produced by a depression of the surface. If the under metal at the surface of the chill extends, it must either crack the face or shear away from it. It seems, therefore, that if the chilled surface occupied the faces and sides of a large number of narrow and shallow gashes in the face of the plate, so as to be sharply broken up, flaking would be prevented. At the same time the surface would be more rigid and braced against, as well as preventing the extension of the metal below. Such gashes need not weaken the plate, as they would be confined to the hardened surface, which is otherwise bound to crack and flake before the interior is extended.

Theoretically the depth of surface chill should vary with the caliber of the projectile to be resisted; for while the zone of its resistance to the advancing ogival increases with that caliber, and the surface already crushed down with its square, the energy of the shot varies with the cube. Efforts to resist greater energies by making the body and back stronger by an increased percentage of carbon have usually led to the plate cracking under impact.

Attention must be paid, however, to the limitations of carbon steel in hardening and toughening. Also to the fact that the change in tensile strength due to tempering follows a different law than the hardness.

Both the tensile strength and ductility of the mildest steel are greatly increased by quenching, though the hardness may be scarcely changed. The same result will be produced on higher carbon steels quenched from a temperature below that affecting the carbon, although, as noted previously, Professor Langley has to a small degree hardened steel by sudden cooling from the temperature of boiling water.

It is evident, therefore, that the more sudden and complete the chill, the greater the increase of toughness in the body and back of the plate. Should the metal be highly carbonized for any considerable depth, however, it would not only lack strength and toughness, but the contraction strains might cause it to crack and flake off spontaneously or at least under impact. If the chilling should be made less severe, or from a lower initial temperature, in order to avoid these external defects, the interior might hardly be toughened at all. It appears, therefore, that as the depth of chill now obtained must in all probability be increased if projectiles of the latest type are to be resisted, the present system of carbonizing and hardening would not be satisfactory. To get the chill in deeper, the carbonization must extend deeper, and the percentage on the surface be higher; this would require greater time and expense in the cementation. In hardening, the higher carbon in the face would prohibit quenching from as high a temperature as now employed, not only on account of the danger to the plate, but on account of the much greater difficulty in controlling or preventing distortion. Should the surface of the plate, however, be covered with fine shallow cracks or serrations spaced from seven-eighths of an inch to an inch and a quarter apart, it would be possible in cementation to give the metal a practically uniform and moderate percentage of carbon to the bottom of these grooves, from which depth it would shade off quickly to the normal. Upon hardening, the surface through which the heat is abstracted having been thus enlarged, it would be possible to chill much deeper, considering the intentionally low content of carbon, than is at present possible.

"Changes in hardness are almost entirely due to changes in the carbon, apparently closely following the changes from cement to hardening carbon. The increase of hardness is practically proportional to the amount of carbon; it is not due to the stresses set up, because both interior and exterior are hardened, though under opposite stresses; also thin bars are hardened more than thick, through cooling more suddenly, though their stresses are less severe. At the same time, while pure iron is placed under violent stress when quenched, still it is not hardened. This is in opposition to Ackerman's theory that the changes in hardness, ductility, structure, and much of that in tensile strength is due *entirely* to compression which forces the carbon into the hardening state; this theory is plainly incompetent."—*Howe.*

Still, Caron found that blister steel after forging contained more hardening carbon than before, and that pressure favored the absorption of charcoal carbon. On the other hand, the effect of compression, as an aid in hardening steel, has been long known. At Moutluçon pressure was applied to steel in hardening when at a cherry red. Liquid steel containing more than 0.50 per cent. carbon is sensibly hardened if cooled under a pressure of from 7 to 10 tons per square inch. The proportion of combined carbon is always greater under pressure than when the metal is uncompressed. M. Clemendeau, in hardening steel for tools, places the cherry red metal in a receptacle it completely fills, and then subjects it to enormous pressure; the greater the pressure the harder the steel.

The fact undoubtedly is that hardness is primarily due to the carbon. Professor J. O. Arnold in a recent essay on the Physical Influence of the Elements on Iron, read before the Iron and Steel Institute, makes the following statement: "That no element except carbon has (*per se*) the power of conferring upon quenched iron the power of abrasion hardness to any extent worthy of consideration. Whether the adamantine hardness of quenched high carbon steel is due to the individual properties of an extremely attenuated carbide of iron or to an allotropic change produced in the iron itself, by the presence of dissolved carbon, there is no evidence to show, nor is the matter of much practical importance since such hardening power is possessed by carbon alone." These are strong statements and yet correspond to the general opinion of metallurgists, although there is still a considerable diversity of opinion among them.

When, however, the method and degree of hardening effect produced by a certain percentage of carbon is considered, it will be found that the chemical composition, rate of cooling, pressure, and temperature, all exert important influences; and to these in consequence have frequently been ascribed the results which, however modified, really pertain to the carbon alone.

Thus high carbon steel cooling past the critical point at 1200° F. undergoes a molecular change made manifest by the evolution of considerable heat, sufficient in amount to retard the cooling. It is said that from this point the metal becomes more and more dense as heated until fluid. The fluid density of steel, the composition of which is not stated, has been given as 8.05 ; in the solid state it was only 7.8. This evolution of heat at 1200° F. is accompanied by a contraction of .004 (Barrette) in a steel containing 0.9 per cent. carbon, which, occurring wholly in the small percentage of carbide formed, must be much greater there. However, by compression the tendency of the metal to expand below the point of recalescence in the formation of carbide is opposed, and the effect of contraction by cooling produced, and hence the cooling is hastened by the further evolution of heat. Doubtless the great depth of chill in cast iron projectiles can be explained by the magnitude of these forces, as that operation increases the specific gravity of the metal fully 3.5 per cent.

A substance expanding in congealing or liquefaction may within limits be compelled to retain its denser state against the influence of heat by sufficient pressure. Conversely, when a body upon being heated expands, it may be led to part with its heat more readily in cooling if subjected to pressure. The same effect is produced on the solution of a salt by pressure as if it was a solid melting.

Professor J. Thomson considers the following to be a physical axiom : "If any substance or system of substances be in a condition in which it is free to change its state [as ice, for example, in contact with water at 0° C. is free to melt], and if mechanical work be applied to it as potential energy in such a way that the occurrence of the change of state will make it lose that mechanical work from the condition of potential energy without receiving other potential energy as an equivalent, then the substance or system will pass into the changed state. Thus the lowering of the melting point by stress is the cause to which is attributed the plasticity of glaciers."

Steel test pieces often show a fracture, the center of which is grey, becoming brighter towards the edge, when, if broken without tension, the fracture is homogeneous. W. Hempel ascribes this to the combination of the carbon under pressure. The increased strength obtained in wire drawing and cold hammering is explained in the same way.

The application of pressure is undoubtedly therefore an important assistance in tempering. It may be said that the molecular attraction, constantly in opposition to the dispersive action of heat, is assisted by pressure, although the latter may only be felt in the exterior layers of molecules.

It is believed that the pressure brought to bear in hardening on the surface layer of a carbonized plate by the initial contractions of the walls of the gashes or cracks, above spoken of, would correspond in its effects to an increased percentage of carbon or a more violent local quenching, thus forming an additional reason why a certain depth of chill could be obtained with a lower percentage of carbon and less danger of distortion.

COMPOSITION OF ORIGINAL PLATE.

Before continuing it is important to consider the influence of the composition of the original plate; bearing in mind the fact that the effect of water tempering should not be confined to hardening the surface, but include a marked toughening of the metal throughout.

On this subject there will be found a great diversity of opinion. Generally speaking, however, this arises from the confusion of the influences exerted by a component on an existing steel alloy with the characteristics *per se* of that component. Liberal quotations are made from the valuable discussions by Professor Arnold, Osmond, Hadfield, Brustlein, and others, before the Iron and Steel Institute.

The presence of chromium in the original plate is advantageous for several reasons. Ordinary cemented cast steel has large crystals, while those of cemented chrome steel are small. M. Brustlein, of the Holtzer Works, at Unieux, France, says: "In chrome steel *the temper penetrates deeper* than in plain steel, having an equal amount of carbon. This is attributed to the great affinity of chromium for carbon, favoring the dissolution of the latter in the metal, and thus maintaining it with greater readiness in the combined state. In manganese steel the same thing occurs; in fact, a small amount of manganese hastens the chilling effect. Chrome steel, however, scales badly, like nickel steel, and the difficulties of its manufacture are very great. First, it requires an intensely high heat for reduction; second, incomparably more rapid solidification than mild steel occurring in the change from white to yellowish white heat; third, the formation of an oxide when exposed to the air which cannot be reduced or entirely separated from the mass of the steel; these difficulties increase with the size of the ingot; fourth, very great shrinkage; fifth, highly carbonized chrome steel burns very easily."

Generally, chromium has a less hardening tendency than manganese or highly carburized steel, but it imparts more tenacity, and the tendency to crystallize by excess of heat is not so great. Manganese steel works better hot under the hammer than chrome steel, but the former works particularly well anyway. Again, manganese steel welds with great facility, while chrome steel welds badly or not at all. "Steel containing a high percentage of carbon and chromium, especially the former, as .77 per cent. C, 5.19 per cent. Cr, will harden when cooled in the air. It is, consequently, self-hardening. Heretofore it has been believed that tungsten compounds alone had this property."

M. Brustlein also says "chrome steel is especially valuable on account of increasing both tensility and elastic limit without diminishing elongation, as would occur in carbon steel, where an increase of tensility invariably means a decrease in ductility." M. Brustlein is wrong there, as Howe has shown how proper treatment of carbon steel increases both elongation and strength. He, Brustlein, says chromium steel also seems to harden more readily. Chromium plays the part of a hardener, even without the intervention of a cooling medium; therefore when such a medium is employed the hardness is intensified.

Hadfield declares: "It has not been proven that a piece of chrome steel of a given diameter would harden more deeply when quenched than a similar piece of carbon steel.

"Probably if the right hardening temperature were obtained for each *class of steel,* it would be found that the chromium steel was tougher after hardening than the carbon steel, and it is also probable that it would harden at a somewhat lower heat, but *that the effect of hardening would penetrate further is not proved.*

"Theories have been advanced that chromium holds carbon in the combined state and that therefore chrome steels harden more readily. Seeing that the carbon present in all steel is in the combined state, whether chromium is present or not, this explanation does not offer much satisfaction. Chrome steel gives great resistance to compression, but in the absence or lowness of carbon it has in this little or no superiority to similar aluminium or silicon steels. So long as the carbon is about .30 per cent. or under, the effect of chromium crystallization is small, but when the carbon is greater the action is more vigorous, or the carbon is enabled to act more vigorously."

F. Osmond, in the Journal of the Iron and Steel Institute, 1887, Vol. II., says: "Manganese retards both the molecular change of iron and recalescence during cooling from a high temperature, or in other words, maintains the carbon in solution and the iron in the condition β, the effect being greater in proportion to the amount of manganese. The same effect is produced by the rapid cooling of steel containing no manganese, so that the presence of manganese exerts much the same influence as the process of tempering, a conclusion which agrees with the known mechanical properties of steel containing manganese. Tungsten has the same property in a still more marked degree; but *chromium appears to produce no similar effect.* Silicon has no influence on the effect produced by manganese (it hardens of itself, however). Sulphur seems to neutralize part of the manganese, diminishing its action. Phosphorus has no appreciable effect on the modification of the iron nor on recalescence."

From the remarks of Mr. Hadfield it would appear that, in order to obtain any characteristic effect of chromium in the heart of an armor plate, it would be necessary to run the carbon there up to a prohibitory point, although the cemented surface would obtain the full benefit of it. In France this difficulty has been to a certain extent overcome by combining the chromium with nickel, which seems to act as a sensitizer, emphasizing the hardening effect of the carbon in the chromium alloy, while retaining the necessary ductility; in fact, toughening the metal rather than rendering it hard and brittle. The celebrated *açier speciale* of St. Chamond is also a chrome-nickel alloy, said to contain .40 C, 1.0 Cr, and 2.0 per cent. Ni.

All of Vickers' Harveyed plates are said to contain some chromium; it is also found in some of Brown's and most of Schneider's. It is extensively used by the French in their protective deck plates, the principal feature of which are their extreme ductility and toughness.

In the United States no extensive experiments have been made with chrome steel armor, the difficulties of manufacture of which are indicated above by M. Brustlein. It is believed that as our armor at present compares very favorably with the Harveyed nickel chrome of St. Chamond, which has been developing for some years, that more is to be expected from an alloy of nickel manganese. In this connection, it is interesting to note the effect of manganese on carbon as indicated in Professor J. W. Langley's equations of annealing and chilling. These were published in the Transactions of the American Society of Civil Engineers, Vol. XXVII.

$$(1)\ \text{Power of annealing} = \frac{\mathrm{Si}}{\mathrm{Mn} \times \mathrm{C}} \times t.$$

$$(2)\ \text{Power of chilling} = \frac{\mathrm{Mn} \times \mathrm{C}}{\mathrm{Si}} \times \frac{1}{t}.$$

A recent process, in which a mild steel body and back are cast upon a bed of ferro chrome and then water hardened, deserves attention. After experiencing the usual difficulties accompanying the development of a new process, most satisfactory results are claimed to have been obtained, the percentages of chromium and carbon averaging about 5.5 per cent. and 1 per cent. at the face respectively, and running out to the normal in 1.5″. If the resistance of the face hardened cemented plate was entirely due to the hard face, rather than a tough body bound together by that face, it might find in this cast plate a dangerous competitor on account of its cheapness. It is feared, however, that the result cannot but resemble somewhat a cast, homogeneous, chrome steel plate, the body and back of which have been weakened.

In this connection, it is worth while to note that M. Montgolfier, Directeur de St. Chamond, declares that although their celebrated chrome-nickel armor increased the velocity to perforate armor of a thickness equal to the caliber of projectile 100 meters, the application of the Harvey process raised that velocity fully 100 meters more.

SECTION IV.

THEORY OF ITS RESISTANCE.

The empirical formulas for the perforation of wrought iron plates differ so widely in their results, as the thickness of the plates or the calibers of the guns vary, that they have been called a disgrace to the science of mathematics. This seems like blaming a good servant for not accomplishing the impossible.*

When it is considered that these formulas represent forced generalizations from a comparatively small number of experiments in which the actual qualities of projectiles and armor, often merely guessed at, were assumed to be identical, the diversity of opinions is explained.

Steel often varies considerably in its composition from heat to heat as well as being strongly influenced by many conditions of temperature and treatment in the course of manufacture; it is therefore much more liable to variations in quality than wrought iron, and fewer general laws as to its behavior can be made. The problem was attempted, however, and the De Marre formulas, believed to be fairly accurate for Creusot steel plates, resulted. In these the projectile is not supposed to experience any change of form while passing into and through the target. As this condition is rarely fulfilled under the conditions of test, there is usually a certain amount of the projectile's energy expended on its own deformation, with a consequent relief to the plate. Especially is this the case when the deformation is of the nature of an expansion of the shell, thus increasing the area directly opposed to its advance. When the plate is hardened, tending to check the projectile suddenly and to crush or break it up, the energy thus diverted is still greater, while that remaining, being distributed among fragments acting in detail, produces proportionately less effect. Evidently the *calculation* of the resistance of a single plate of this description, even though the method and extent of its actual resistance had been determined by experiment, would be complex enough; and if it is sought to generalize, the irregularities in quality are so great as to render the deductions of little value.

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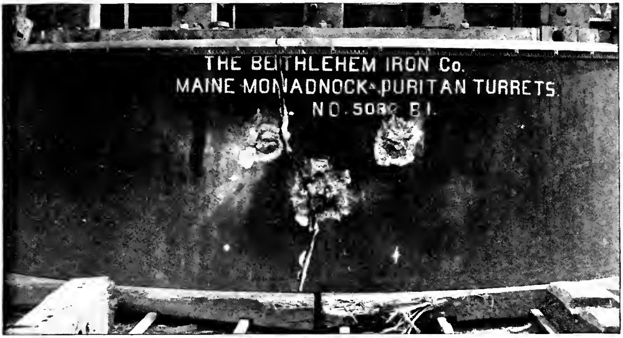
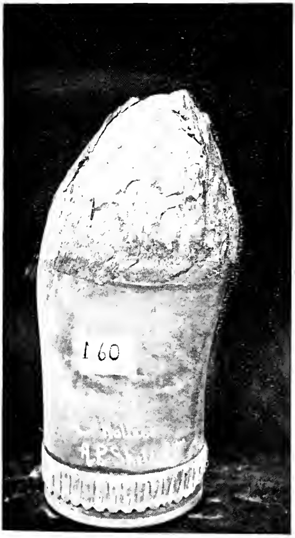
* A very interesting discussion of these variations by Lieut. E. M. Weaver, U. S. A., appeared in the October, 1893, number of the Journal of the United States Artillery.

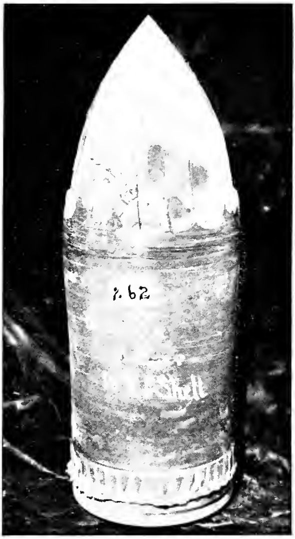


Has numerous bending cracks confined to the face hardened surface, 1'' to 1.25'' deep and .03'' to .1'' wide. None were extended or deepened by impact.



No. 312a.—Showing projectile. Test of Midvale-Holtzer 10-in. A. P. Shell No. 160, against Oregon's 17-in. Harveyed nickel steel barbette plate B-107, group 15, Carnegie Steel Co. Impact No. 6; striking velocity, 1983 f.-s.; striking energy 13646 ft.-tons; penetration 12½''; rebounded badly set up, twisted, scored, fuzed, chipped, and out of axis in the ogive. Shell increased in diameter at bourrelet to 12''; shortened 6.06''.

N. P. G. letter No. 697, Sept. 14, 189.



No. 311a.—Showing projectile. Test of Midvale-Holtzer 10-in. A. P. shell No. 262 against Oregon's 17-in. Harveyed nickel steel barbette plate B-107, group 15, Carnegie Steel Co., made Sept. 15, 1894. Impact No. 5; striking velocity, 1983 f.-s.; striking energy, 13636 ft.-tons; penetration 30''. Back bulge star cracked. Shell rebounded entire, chipped and cracked around ogive's surface, and increased in diameter at bourrelet to 10.87''; shortened 1.8.''

N. P. G. letter No. 697, Sept. 14, 1894

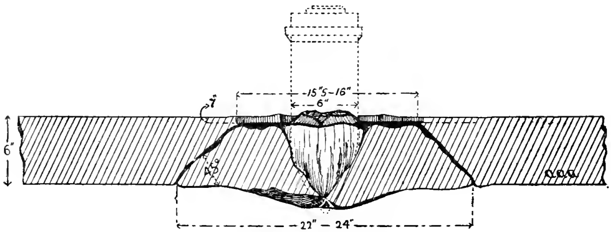
They become even still more unreliable in considering hard faced armor where the chemical composition is irregular, and the physical characteristics vary from the hardest chill on the surface to wrought iron-like softness at the back.

Variations in quality of armor-piercing shell, even of standard make, may occasionally be expected; that still greater ones are contained in the larger and cruder armor plates is equally true, so that when the two are about evenly matched, it is difficult to determine within narrow limits what is a normal result. The resistance of such plates cannot, even with the present comparatively simple condition of the art of face-hardening, be made a subject of calculation; and different applications of the processes of cementation and hardening, so little understood at present, may render the subject much more complex in the future.

The popular impression is that face-hardened armor resists the projectile by crushing it from the point; this rarely occurs, except in the case of very inferior projectiles, which go to pieces like a Prince Rupert's drop upon the point being crushed; or, in the case of soft shells, the point upsets and the head expands into a mushroom (see photos 315 and 326*a*). Many good projectiles retain sound and nearly perfect ogives, two-thirds way from point to bourrelet, after having forced the head into a plate (see photos 53, 91 and 311*a*). Others have the point rubbed off and the sides of the ogival abraded, scored, and twisted (see photos 310, 312*a*, 314*a* and 325*a*), but in none of these cases does the destruction of the shell start from the point. In nearly every instance, the failure of the projectile is along a conical shearing plane inclined about 45° to the axis of the shell with its apex at the center from which the head of the chamber is described. This is due to the unsupported walls of the shell splitting longitudinally and sliding over the head which has been arrested by the plate. An instance of this is shown in the excellent Texas side armor plate from Bethlehem; a fragment of the wall of the shell is embedded in the plate by the side of the ogival. (Fig. *A*.) It will also be seen in the same figure that the crater surrounding the shot, usually ascribed to the impact of fragments of the body and base, is often nothing more than the flaking or prying off of wedge-shaped fragments of the brittle surface.

Certain of the concentric cracks seen around impacts are due to the blows of the walls of the shell, the upset and fused ends of which bear witness to their behavior. Others again are due to the cracking of the brittle surface upon the plate being "dished." These cracks have been noticed in many compound plates; even Grüson armor has shown them. There is the greatest difference, however, between the behavior of thick and thin plates in this respect, the former, as a rule of hammered or pressed steel, attacked by calibers but slightly exceeding two-thirds of their thickness, but which nevertheless averaged over one-eighth of the width of the plates; the latter, of rolled steel, attacked by calibers equal or even one-third greater than their thickness, and which rarely exceeded one-twelfth the width of the plate. In thick plates, the impact is usually surrounded by a shallow crater formed by displaced wedge-shaped chips of the brittle surface, and from that short radial cracks extend. The backs would seem less equal to the task of holding the mass together than in the case of thin plates, for cracking is far more frequent.

In the thin plates, there is usually considerable flaking of a nearly uniform depth about the impact. The surface of this flaking, and especially the fracture at its edges, is concoidal, appearing to follow a wave form originating at the impact. A remarkable peculiarity of every impact noted on good, thin, rolled, face hardened plates



SECTION OF AN IMPACT, PLATE NEARLY MATCHED.*

is the similarity in shape and proportional dimensions of the fragment broken from the plate.

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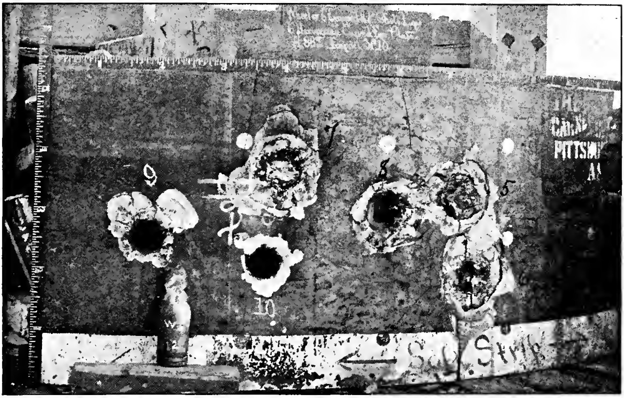
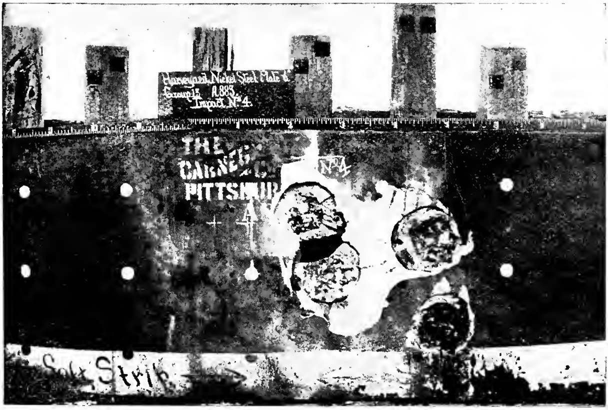
* These dimensions were taken from a curved plate. In flat plates the angle is nearer 35° than 45°, which would indicate that, with regard to the backing, the resistance of a curved face hardened plate to normal impact is slightly less than that of a flat plate.



No. 336.—Test of experimental 6″ Wheeler-Sterling A. P. shell with soft metal cap, against 6″ face hardened nickel steel curved plate A—883, Carnegie Steel Co. Impact No. 10. Striking velocity, 1700 f.-s.; striking energy, 2006 ft.-tons; projectile penetrated plate, and 3 feet oak backing; recovered with portion of point broken off, and cracked. Shell shown in front of plate.

Impact No. 5 = 6″, Wheeler special, . . . 100 lbs., at 1800 ft.-s., penet. 3.2″.
" " 6 = 6″, " magnetized, " " 1900 " " 4″.
" " 7 = 6″, " " " 2000 " " 3.6″.
" " 8 = 6″, " " " 2100 " " 4.4″.
" " 9 = 6″, " capped, 104 lbs., " 1900 " through all.
" " 10 = 6″, " " 105 lbs., " 1700 " "



No. 265.—Further experimental test of 6-in. curved face hardened steel plate A—883, Carnegie Steel Co., which had been rejected on account of surface cracks. Carpenter 6-in. A. P. projectile, lot 2; striking velocity, 2000 ft.-s.; striking energy, 2776 ft.-tons. Line of fire normal. Estimated penetration about 4½″. Projectile broke up. This impact marked No. 4, N. P. G., letter No. 382, May 25, 1894. Plate unbacked.

Impact No. 1 = 6″; 100 lbs. at 1800 ft.-s. penetration = 3.2″ (shown below No. 4).
" " 2 = 6″; " " 1800 " " = 2.4″ (shown to right).
" " 3 = 6″; " " 2000 " " = 4″ (shown below No. 2).
" " 4 = 6″; " " 2000 " " = 4.5″.

In the sketch showing a section of a 6″ plate attacked by a 6″ projectile, it will be seen that the face has scaled over a diameter of 15.5″; the frustum of a cone starts from this edge of the sound surface, curving down quickly into the slope of a 90° cone. There may be several concentric cracks around the impact, and each one will be found to be the origin of a similar conical surface. These conical back bulges can be initiated with comparatively light blows, yet possessing the same general dimensions and shape as with the severest impacts, only in the latter case the frustum may be completely detached. Perforation, however, would occur by the projectile's head breaking out a small fragment directly opposed to it. A somewhat similar behavior is seen in the case of the third 4″ impact on the 3″ plate, No. 4.

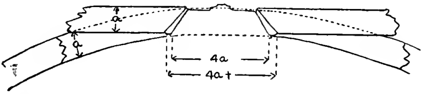
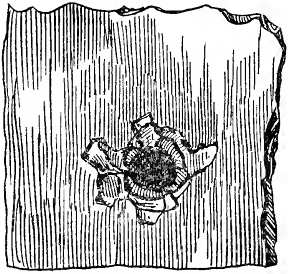


FIGURE SHOWING ROUGHLY THE COMPARATIVE AREAS OF BACKING SUPPORTING BACK BULGES OF CURVED AND FLAT PLATES.

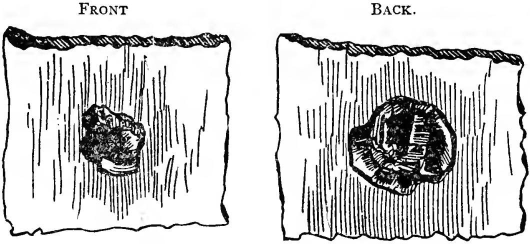
Similar bulb-like foliations or sheathes may be seen in the cases of plates 935, 3″; 883, 6″; 874, 6″, and in the accompanying sketch of Krupp's gas hardened 10.25″ nickel steel plate. The impact shown is that of a 112-lb. projectile moving at 2160 ft. s.



KRUPP'S 10.25″ NiS, GAS HARDENED.
Attacked by Krupp 112-lb. A. P. shell at 2160 ft. s., 12.2″ penetration.
Showing sheathes and rear cone.

velocity. The plate was nearly matched, the perforation being 12.2″.

In plates where the body and back is hard and rather brittle, as in many of the earlier all steel face hardened plates, this peculiar effect is not produced. Projectiles inferior to the plate crush and chip away a crater in its face in which the ogival is welded. Projectiles superior to the plate either crack it apart or break a rough-shaped cylinder out of it, much as in the case of hard and very tough homogeneous steel alloy plates. (See sketch of Hadfield's 5-inch manganese steel plate.) Thin face hardened plates usually fail in this manner when perforated by undeformed projectiles.



HADFIELD 5-INCH MANGANESE STEEL, HARDENED.
6″ Holtzer at 1400 ft. s.

The question may be asked, If the plate is going to fracture under the blow, why must it give way over an area of from 16″ to 24″ in diameter, when one of from 6″ to 14″ would have sufficed to allow the projectile to pass? The reason must be that the projectile's head, forced in as it is, acts as the keystone of an arch exerting pressure in every direction normal to its ogival. At some points, located on a circle about 16″ in diameter, the opposition to that pressure by the rigidity of the surrounding plate, supported and stiffened by its hardened face, is sufficient to shear the two apart. It is evident, however, that the resistance to the advance of the projectile is far greater than the energy required to punch out a hole about three times its diameter; that is, a peculiar resistance is experienced by the shell. In some instances the shattered ogival appears welded to the plate; more commonly, however, an extremely hard shell head is squeezed, scored and ridged by the fragments of the hard surface carried in by it. Hence it is that so much assistance is lent the shell by a soft cap forced into the plate with and around it, and to a certain extent sheathing the hole and protecting the shell. This seems at least very plausible, as when capped shell perforate the plate there usually appears to be no cone formed. The plate, however, is dished in the vicinity of the hole perhaps 0.5″, at any rate far more than in the case of a non-perforating shell, which still may have badly racked a considerable area. The advantage of a rigid backing in the cases illustrated by this figure are apparent. Some doubt may be felt of the value of the ogival head, however, in such cases. The plate having broken along the sides of the cone, the energy expended in forcing the ogival into the plate must, in a measure, have been wasted. It would seem that a similar but much smaller cone would have been broken out by a flat-headed projectile, in which case all the energy would be concentrated on the area opposing the projectile. This, in fact, is probably one of the effects of the cap. It is interesting to note in this connection that in a trial of Grüson chilled iron armor with flat-headed and pointed projectiles in 1885 the mean penetration of the former was 1.935″, and of the latter only 0.459″.

The total energy of a rapidly moving projectile at the instant of impact has been expressed in two ways, as the effect expected is that of penetration or racking. In the first case, the tons of energy per inch of circumference gives the relative punching effect very accurately in soft, thin plates, provided the projectile is not deformed. In the second, the tons of energy per ton of plate gives relatively the amount of energy a hard plate is required to absorb. It is evident that the important questions of location of impact, projectile and plate deformation, and transformation of energy into heat, are here out of consideration. Actually beyond a certain point for each combination of energy, thickness and quality of plate, and rigidity of structure, the mere increase in weight has nothing whatever to do with the plate's resistance.

The limited dimensions of armor plates and the occasional location of impacts near the edges qualify the results, whatever theory is advanced; still, the principles developed in the attack of the central region of a plate of indefinite size are fundamental and something may be gained from their consideration.

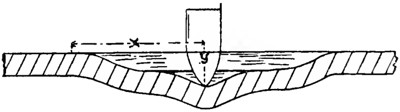
The comparison of tons of energy delivered per ton of plate is obviously always unfair to the plate, unless it be in each case absolutely homogeneous and symmetrically disposed and supported around a normal impact. In addition, to obtain the comparative racking effect pure and simple, the expenditures of energy in penetration and deformation must be the same.

On the other hand, the energy per inch of cross-section of shot, especially with different calibers, gives no reliable comparison, unless the shots strike normally, escape deformation, and each inch of their sections do equal amounts of work. This is evidently impossible except in a disk-shaped projectile of molecular thinness. If, however, we regard the impact of projectile upon the center of a face hardened plate as the arrival of a succession of thin disks held in elastic relation to each other by intermolecular forces, perhaps the mutual reactions of such a plate and shell may be better understood.

A soft plate, the behavior of which is better known, if struck by a punch, stretches before it and tears away circumferentially, a disk being forced ahead while the elongated fibres forming the walls of the cavity are pushed aside and compressed into the body of the plate until the displaced metal crowds the surfaces adjacent to the impact up into front and back bulges. The diameter of these is chiefly influenced by the elastic strength of the metal and their height by its softness or ductility. That is, in the case of metal having a high elastic limit and hence lying near the failing point, a flow of metal started by pressure at the impact would be accompanied by a comparatively slight movement of the metal over a considerable area. In a metal having a low elastic limit the volume displaced is equal, but the movement under the same circumstances would be local. Probably a very fair comparison of the toughness of two plates would be the cotangents of the angles of their bulges under similar penetrations. If the metal lacks ductility, the great difference in displacement of adjacent particles must be accompanied by its rupture, the fringe flakes off or even a crater may be formed.

Let the behavior of a homogeneous oil tempered plate be considered, when subjected to pressures under the elastic limit. The punch depresses the hard and elastic surface immediately in front of it a distance y, the radius of the base of the depression thus formed being x. Considering that the figure is approximately a cone, the extension of the elements would be $\sqrt{x^2+y^2}-x$. The extension of the metal will, however, be extremely small even when it has a high elastic limit, in which case x will have considerable length.

This subject has been touched upon by a number of physicists in the investigation of the absolute measurement of hardness; with this difference, however, that, in the determinations of hardness, uniformly slowly applied pressures were alone considered, so that no wave movement due to the inertia of the material resisting a rapidly extending stress, as shown in the exaggerated sketch above, could occur. A most interesting memoir on the subject, by F. Auerbach, translated from the German by Carl Barus, may be found in the Smithsonian Report for 1891. Auerbach's experiments were founded on a theory by Hertz "that, if a sphere be pressed upon a plane so as to produce a surface instead of a mere point of contact, the impressed area would increase, within the elastic limit, as the two-thirds power of the total pressure, it will also increase as the two-thirds power of the radius of the sphere."



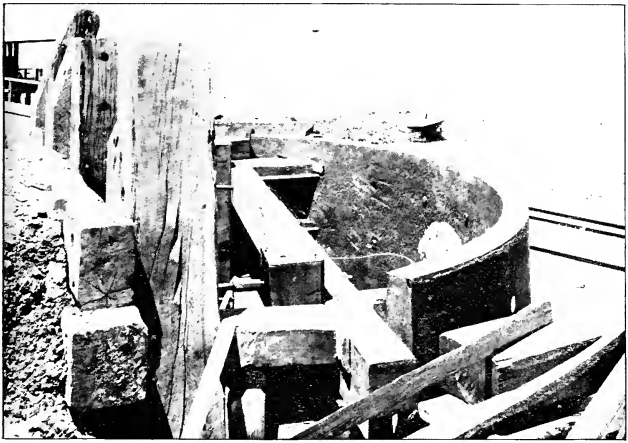
The y ordinates are greatly exaggerated.

It was found that the hardness increased with the curvature of the sphere or lens; that is, although both lens and plate be cut from the same material, rupture will always occur in the latter, the former remaining intact. He calls attention to the analogy between the increased resistance of the convex lens and the surface tension of liquids. With that significance, the behavior of the lens and plate would resemble that of a truss and simple beam respectively. The metal of which a projectile is composed may be made at least as hard and certainly of superior quality to that of the surface of a face hardened plate. There is no reason, apparently, why the superficial film of the latter should not be ruptured under pressure, therefore, before the point of the former. The support of the underlying layers, though they add to the resistance of the outermost one, do not increase its hardness. Upon impact the point of the projectile receives a concentrated support, as it were, from the better placed layers behind it crowding forward. There is no reason at all, therefore, why a sound and properly made projectile of *better material than the plate* should break up from the point. To do so, as Captain Tresidder has said in a recent article entitled "Notes on Armor Plates and their Behavior under Fire" (Occasional Paper No. 7 of the Royal Engineers), the disintegration of the projectile must commence the instant the point strikes the plate, but that will hardly occur even with the most inferior projectiles, unless the superficial resistance of the plate far exceeds their energy of impact. The deductions of Captain Tresidder appear to be drawn from data which he has seen fit to withhold, they are so widely different, however, from experience obtained in this country, that advantage is taken of this opportunity to comment upon them; not for criticism's sake, but to draw out views, if existent, not apparent to the writer.

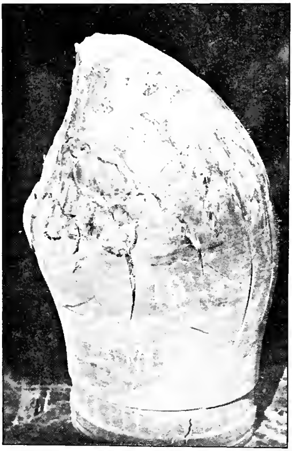
To be just, Captain Tresidder's paper was written in 1893, it was published, however, with a few modifications, in October, 1894. His theory of the smashing of the projectile upon a face hardened plate is that of pulverization on impact progressively from the point; this is in keeping with his statement that the action of the soft iron cap employed on certain experimental projectiles is to support the point laterally, so that the initial splitting cannot be done without bursting the cap, as "pulverization must be initiated before penetration or it will not occur at all."

A multitude of parallel, conical, shearing planes are supposed to form in the projectile from the point (which becomes in consequence a spindle, towards the base) by the arrest first of the point, then successively the sheared conoidal segments which split over the point and the other segments gone before. This breaks the shell into a myriad of fragments, which are then mashed together in the indent. Though how there can be an indent if the shell is pulverized and has its energy divided among minute fragments is inexplicable. The whole theory is, in fact, inexplicable even though confining its application to chilled iron projectiles.

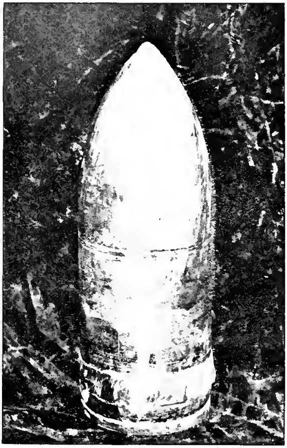
If an inferior projectile, or for that matter a fairly good one, be fired against a very superior face hardened plate at too low a velocity to penetrate, its energy may be sufficient to cause it to



No. 258.—Experimental test of 6.-in. curved face hardened nickel steel plate A—883, group 13, Carnegie Steel Co., which had been rejected on account of surface cracks. Photograph showing method of securing plate at the two ends without backing.



No. 325a.—Test of Carpenter 10-in. special forged steel A. P. shell No. 15 against Massachusetts' 17-in. face hardened nickel steel barbette plate No. 5523, B. I. Co., group 15. Impact No. 5 showing shell; striking velocity, 1930 f.-s.



No. 335a.—Test of experimental Wheeler-Sterling 6-in. A. P. shell with soft steel cap on point against 6″ face hardened nickel steel plate No. 883, Carnegie Steel Co. Impact No. 9: striking velocity, 1900 f.-s.; striking energy, 2506 ft.-tons; line of fire normal. Photograph of projectile after recovery.

fly to fragments, hardly leaving a mark on the plate. This seems to bear out Captain Tresidder's theory and contradict that advanced with regard to the relative hardness of a sphere and a plate. The latter did not contemplate *impact*, however, or for that matter still less, *impact with insufficient energy to penetrate.* This stoppage of the projectile on the surface of the plate would correspond in its effect to a much greater energy distributed over a greater distance, only in the latter case the head of the projectile, having penetrated, would be supported by the surrounding metal.

With higher velocities, however, good projectiles will penetrate until the resistance has increased sufficiently to counterbalance or nearly counterbalance their remaining energy, when the shell, being stopped, is much in the same condition as the projectile fired at an impenetrable plate with that remaining energy. The result is that, as a rule, the unsupported part of the projectile splits and shears over the head gripped in the plate.

What the face hardened plate does is merely to present so great and concentrated a resistance to the projectile's advance at some one instant in the impact *as to stop it*; disintegration follows as a matter of course.

The loosely worded explanation that face hardened plates stop the projectile by breaking it up and distributing its energy, puts the cart before the horse, the effect is confused with the cause. A broken projectile or some of its fragments may get through a plate, but if it does, these fragments have acted together as a unit; the projectile cannot have been wholly crushed though the entire resistance of the plate has been expended in breaking it up.

In connection with the above, the following tests may be interesting. The plate was the Brooklyn's 3-inch Carnegie face hardened nickel steel ballistic plate. The projectiles were of service 4-inch Wheeler-Sterling type, with and without caps. They were of good and uniform quality and composition.

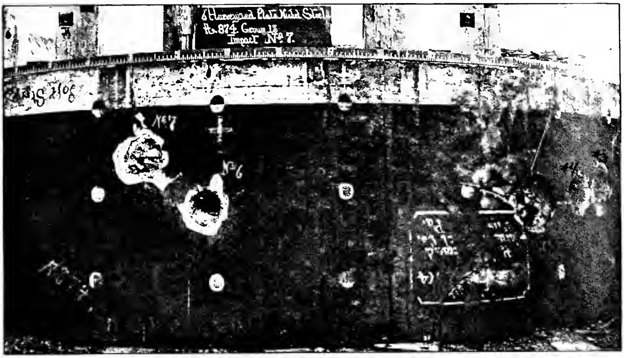
See accompanying photo.

No. of impact.	Projectile.			Result.	
	Kind.	Weight in lbs.	Velocity ft. s.	Projectile.	Plate.
5	Capped.	34	*600	Smashed.	Impacts 5, 6, 7 and 8, upon same spot. Saucer-shaped depression ⅛'' deep.
6	"	35.5	*600	"	" " " ⅛'' "
7	Service.	32.5	600	"	" " " ⅛'' "
1	"	33	1206	"	Penetrated 0.5'', plate dished 0.3''.
2	"	33	1357	"	" 0.5'' " " 0.4''.
11	"	32.5	1600	Head into backing, body smashed.	Some flaking, concentric back cones started.
10	Capped.	35.5	*1600	Through all into butt, in three pieces. Point scored and abraded.	No sign of back cones, back bulge cylindrical, punctured out in shape of head.
9	Service.	32.5	1700	Through all into butt, in two pieces. Point smooth and unhurt.	Slight flaking, no appearance of a conical back bulge. [Undoubtedly a superior projectile.]
8	Capped.	34.5	*1700	Through all whole, uncracked. Point scored and ridged.	Considerable flaking.
4	"	35	*1700	Through all, broken in several pieces. Point scored and ridged.	Some flaking. Back cone initiated.
3	Service.	33	1800	Body smashed, head fast in back cone.	Entrance 6.25'' in diameter, back cone separated 0.5'', but held up by the backing.
				* The velocities were estimated for 33-lb. projectiles. Those given for heavier ones are therefore slightly too great.	The white chalk marks on the plate are concentric cracks formed during the test.

There is much to be learned from these tests, even allowing for a certain variation in the plate from point to point, although the impacts were closely grouped, and allowing for a still greater variation in the separately cast, forged, and treated projectiles; the latter differences being perhaps further accentuated by variations in velocity, angle of impact, etc.

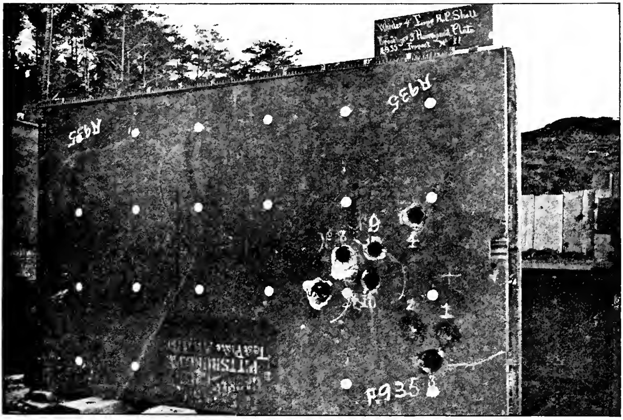
It appears from the above that an energy incapable of affecting the plate may still destroy the projectile; also that the plate may exert sufficient resistance to break up the shell without destroying its point, and finally that the cap does *not* support the point against splitting, but rather eases both plate and projectile under impact.

It may now be asked, Of what use is hardness on the surface if it does not serve to crush the point of the projectile? The answer is that the more rigid the surface, the more certain that the energy of impact will be widely distributed while the resistance of the entire thickness of the plate is brought to bear against the advance of the projectile, as the displaced metal can only flow to the rear. At the same time, when penetration is effected the projectile carries



No. 249.—Experimental test of 6-in. nickel steel face hardened plate A—874, *without backing*, Carnegie Steel Co. 6-in. Carpenter projectile; striking velocity, 1800 f.-s.; striking energy, 2249 ft.-tons; projectile broke up, head welding into plate. Back bulge forced out 1¾″ and star cracked. This impact marked No. 7. N. P. G., letter No. 354, April 25, 1894.

Impact No. 6 = 6″, 100 lbs., at 2000 ft.-s., 2776 ft.-tons.
" " 7 = 6″, " " 1800 " 2249 "
" " 5 = 8″, 250 lbs., at 1472 " 3754 "



No. 334.—Test of experimental 4-in. Wheeler-Sterling A. P. shell No. 1268, with soft metal cap, against Brooklyn's 3-in. face hardened nickel steel side armor plate A—935, group 14, Carnegie Steel Co. Impact No. 4. Striking velocity, 1700 f.-s.; striking energy, 662 ft.-tons. Projectile penetrated plate, backing, and broke up, pieces being recovered about 18″ in the sand.

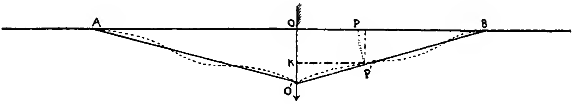
No. 350.—Test of Wheeler-Sterling 4-in. experimental A. P. shell No. 15, without cap, against Brooklyn's face hardened nickel steel side armor plate A—935; striking velocity, 1600 f.-s. Impact No 11. Shell penetrated about 6 inches, and broke up; point welded into back bulge.

Impact No 1 = 4″, 33 lbs., at 1206 ft.-s.
" " 2 = 4″, " " 1357 "
" " 3 = 4″, " " 1800 "
" " 4 = 4″, 35 lbs., " 1700 " (special capped).

with it a mass of jagged, untractable fragments which greatly impede its advance.

A very important accompaniment of hardness is elasticity, which increases, however, much more rapidly than the hardness does. It is, of course, of special value under impact, permitting a greater depth of plate to aid the surface.

Now, the velocity with which the pressure increment at any instant is transmitted over the stiffly elastic surface is far greater than that of the advance of the projectile, so much so in fact that the assumption is not difficult, that the depression is due to the position of the advancing shell at the same instant rather than its position an instant before.



Let *AB* represent the original plane of the surface of a thin plate, and *O'*, *P'*, the position of points *O* and *P* when the surface is depressed to its elastic limit by a force acting along *OO'*. The correct shape of the depression is represented by the dotted line. The radius of the circle on which any point *P* is located has been increased from *OP* to *KP'*, and this circle is therefore in a state of tension. Had the element *OB*, in being pressed down into the position *O'B* extended equally over equal distances, the depression would be a true cone, every point of which would be subjected to equal circumferential and elemental tensions, while the base *AB* would be indefinite in extent. Such a condition would only result when the elastic limit was zero. It is apparent that the stress transmitted through any unit length of a concentric zone or circle, such as that passing through *P'*, must be inversely proportional to the radius *KP'*. In the same manner the extension of that unit, under the elastic limit, will be inversely proportional to *KP'*. In fact, the depression will be of the character of a semi-cubic parabola.

Now, if the pressure is increased above the elastic limit, the metal, if ductile, near the center *O'* would elongate rapidly, allowing the shell to advance, carrying the metal down before it; this action would result in the plate being left dished and without a fringe, as in fact is the case when a comparatively thin plate is attacked by a large caliber projectile.

In the case of a thicker plate or a smaller caliber for the same plate, however, the case is different. The initial tears, before the point, release both radial and circumferential tensions, the points of the sectors thus formed draw back and the maximum tension is carried to a zone outside that which has just failed, extending the radial cracks and permitting the point to advance and attack a second layer in a similar manner. The free points of the sectors are then forced out of the way in the direction of least resistance, curling up about the point forming the "fringe." There appears to be a great regularity in the number and position of radial cracks or tears as shown on the back bulges of wrought iron and simple steel plates, as well as in the front bulge and fringe of steel plates. Doubtless the location of the first crack formed in the highest stretched zone of a fairly uniform metal is at its least ductile and strongest point. To permit this zone to stretch on one side more than the other would require a side movement of the shell, or the metal to flow around it, becoming attenuated on the ductile or cracked side and banking up on the other. The zone, barring such a side movement of the shell or, owing to the very small time limit, improbable flow of metal, must stretch equally in sensibly equal distances; the hardest and least extensible portions would therefore be the locations of the initial tears which would also be spaced quite uniformly about it. This explains why the direction and location of the tears in wrought iron plates seem so little affected by the fibre; also why on occasion a whole section of fringe or bulge will be broken out through its failure to extend.

The length of the cracks would undoubtedly be a function of the elastic strength of the plate. Thus, the point of a shot having opened a stiffly elastic plate starting radiating cracks, the more the points submit to bending, the more distant zones would be subjected to stretching beyond their elastic limit continuing these cracks. At the same time, the surfaces of the points being stretched radially more than the metal beneath, concentric cracks might also be initiated.

After the point has passed the surface, the latter is held down by its cohesion to the intact stratum of metal added to the friction of the shell on the walls of the opening, but resists with all the elastic strength of a layer of metal increasing in thickness as the shell advances. Should, now, the advancing plane of greatest stress pass through a weak spot, or should the accumulating elastic strength of the front part become equal to the undertaking, it will pull away and a circular lamellation be formed which will practically serve, so far as the point is concerned, as the face of a new plate.

It is evident, that in the passage of a shot through a plate, the formation of every lamellation is accompanied by the liberation of an amount of energy in the projectile necessary to bind down the preceding stratum of the plate, and which is also indicated by the tearing away of the reacting face, or by an apparent accession of energy in less elastic plates by breaking out the back bulge. The toughest plate is undoubtedly the one in which there are numerous incipient and no developed lamellations of this sort, for their entire absence would only occur in an extremely soft and weak plate, or an extremely hard and brittle one.

Consider now a thin, rolled, face hardened plate having a soft but tough back. The hard, thin surface being very stiff and elastic, the cone of depression will be wide spread, shallow, and supported by the back over a considerable area. Should it crack radially, as it must do quickly under stress, it is still held together or bridged by the back, thus permitting still further bending and extension of the supporting area before penetration; this again leads to a further extension of the radial cracks and stretching along them of the back. The stiffer the combination of face and back, the greater the area of the plate supporting the impact. The appearance of concentric cracks in the face indicates that the hard face is too thin or the stiffness of the back is insufficient. Had the back been weak and the hard face thick, the brittle behavior of the latter would have characterized the impact. Such concentric cracks are seen in the photo of the 3″ side armor of the Brooklyn. If the hard face had been too thin or soft, a front bulge might be formed as well as a fringe which would flake off. If the hard face was thicker and the back gradually less hard and strong, the best effect would be produced. By the time the surface layer had been bent to the point of cracking, the metal beneath would have communicated the stress though a greater and greater area as it was transmitted to the back of the plate.

Thus far the hardened surface, where it has not been shattered or flaked off, has bound the metal below it together, preventing its extension. And this is the true object of the hardened surface; not, as seems so commonly supposed, to, of itself, shatter the projectile, the soft back being merely to hold its fragments in position, as in compound armor. The hard surface and the metal immediately below it have for their duty the prevention of all forward and lateral displacement of the metal beneath. This would be difficult enough, anyway, on account of its own rigidity, but the assistance it has demanded from the hard face is frequently seen in the latter's extensive flaking. There being no front bulge nor fringe, the metal before the projectile is carried in, gripped between it and the surrounding walls. It still binds the softer metal together, causing the entire thickness of the plate to resist as a unit, even though being incapable of flow, it is ground to fragments, which in turn score, fuse, and abrade away the surface of the ogival of the projectile.

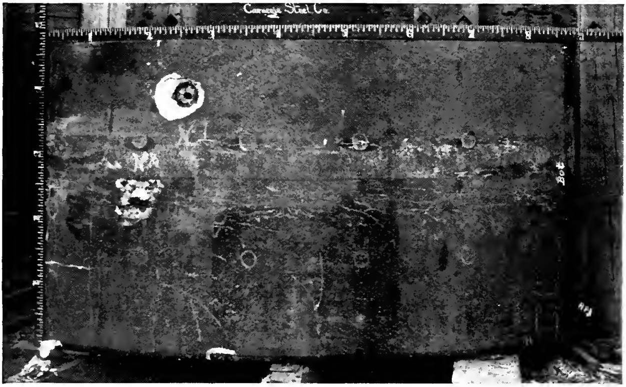
The enormous increase of resistance in face hardened armor is brought about in this manner, not simply because it is more difficult to force the point of the projectile through the inch of hardened steel face. It is evident that, while a certain thickness of hard face is necessary to secure the best results, if it readily flakes or shears away from the metal beneath, a point is quickly reached beyond which its increased thickness is of no particular advantage, as it would fly to pieces immediately upon being struck. If this hard face is, however, carried into the back a slight distance in a series of small gashes or pockets, its stiffness would not only be greatly increased but shearing or flaking prevented by the hooks or protuberances extending into the softer metal. At the same time the advantage of a thicker hardened layer would be obtained without detracting from the elasticity and toughness of the body of the plate.

When a soft plate brings an undeformable projectile to rest it is done gradually, and if the plate offers no sudden change in its resistance as the projectile penetrates, it must have regained a position of equilibrium when the latter finally stops. The structure may have moved, bolts snapped and the plate been set back, still the reaction is directly opposed and equal to the action so long as it continues. In the case of the rebound or disintegration of the projectile, the case is different. The balance of forces is suddenly destroyed, leaving a large amount of unbalanced energy in the plate which must vibrate as a bell under the blow of a hammer. The bolts and fastenings of face hardened armor should therefore be of the toughest, most elastic quality, though not necessarily, in thin plates at least, more numerous than in the case of softer armor. An important consideration in this connection is the peculiar weakness of non-homogeneous armor to vibration. If the method of resistance contemplates the destruction of the projectile, then vibration must ensue, and the tendency of these vibrations to be uniform in amplitude and velocity at equal distances from the impact requires equal duty of strong and weak parts; the same play of those elastic and free to move as those bound down by bolts or otherwise stiff and brittle. Now, the amplitude of these vibrations are a function of the elasticity of the plate in the vicinity of the impact, and though it diminishes as it recedes, a less elastic portion of the plate called upon to vibrate to this extent may be unable to respond and will crack. Thus isolated cracks are sometimes formed at distant points, and in one instance (see figure showing 4″ Brooklyn barbette) repeated impacts on one end of a plate shook off the other and unsupported end. Similar occurrences have been noted in compound plates.

The amplitude of vibration on the surface exceeds that on the back by nearly the amount of elastic compression and extension of the thickness of the metal. To make it clear, we may suppose the plate made up of thin flexible sheets of steel separated by layers of rubber, when the actual movement of the last or back sheet would be less than that of the face by the compression of the rubber between; and this would be less and less for each layer, as the force transmitted was distributed and expended in the compression. Now, if one of the steel sheets should be replaced by a thicker and stiffer or less elastic one, the vibrations of the latter through having less amplitude must cause not only a shearing stress along its face, but a considerably greater tension there on the rebound than exists at any other plane. Hence, as would naturally be the case when this unyielding stratum occurs at the junction of the layers of a compound plate of which the face has great elasticity, and the back, lead-like, tends to retain the shape of the hollow of the initial wave, the face is apt to tear itself away when it takes the form of the crest. This is the serious objection to compound armor, and in fact, to all hard faced armor in which the face, while preserving its continuity over large areas, differs in a marked and abrupt manner in elasticity from the metal beneath. (See photos 259 and 265, plate *A*883, showing flaking.)

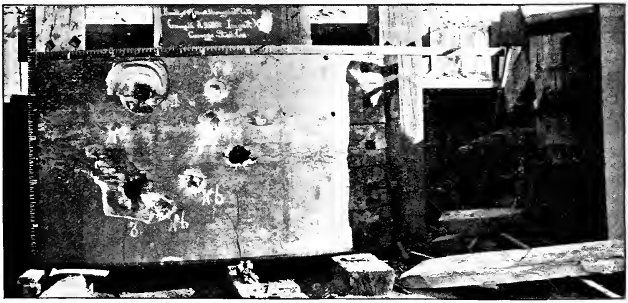
The photograph of plate *A*883 shows how considerable flaking may occur in even a most excellent plate where a superficicial, continuous, and very hard chilled face is supported on a tough but extensible back. Many methods have been devised for overcoming flaking of this sort in compound armor as well as preventing the extension of deeper cracks. In 1877, Whitworth set hard steel plugs, intended to break up the projectiles and to prevent the extension of cracks, in a soft steel plate. Later he applied the same principle to other plates by covering the armor with small plates of hard steel, intimating that the best way to limit the cracks in steel would be to "manufacture" them. In 1883, Whitworth is quoted as saying, "that an armor plate of compressed steel, built up in segments in such a manner as to prevent the extension of a crack or split beyond the limits of the segment in which it was produced, would suffice not only to resist but break up any projectile of an ordinary character." In 1878, a Cammell-Wilson patent proposed to localize cracks by soldering plates to the face of the armor. In the same year, Ellis patented the introduction of wrought iron bars in the surface of compound plates for the purpose of reducing the lengths of cracks in the steel when perforated by shot. A far simpler, if not more efficacious, method than any of these would be merely to gash or score the hard film on the face hardened plate. These gashes, pockets or corrugations would also serve not only for the more expeditious and better controlled cementation, but would permit deeper chilling in hardening; the surface would be more rigid, less inclined to flake, and shearing away from the soft back would be prevented.

That such gashes or openings forming breaks in the continuity of the hard surface do not detract from the plate's resistance is evident, as on account of the rigidity and brittleness of the surface the whole support of the back of the plate cannot be felt until the



No. 333.—Ballistic test of Brooklyn's 4-in. curved face hardened nickel steel plate A—958½, group 16, Carnegie Steel Co. Top end to the left. Impact No. 2. Carpenter 4-in. A. P. shell, No. 1492, lot 5; striking velocity, 1595 f.-s. (specification velocity for 24'' backing); striking energy, 583 ft.-tons. Impact in a group of horizontal surface cracks ⅜'' to ⅝'' deep, below soft strip. Shell smashed on plate, probable penetration 1''. Plate irregularly scaled around impact, scaling confined to old cracks. Surface cracks not developed; no new ones started.

Board report, N. P. G., letter No. 740, October 10, 1894.



No. 332.—Ballistic test of Brooklyn's 4-in curved face hardened nickel steel plate A—958½, group 16, Carnegie Steel Co. Top end to the left. Impact No. 8. Carpenter 4-in. A. P. shell No. 120 (no lot); striking velocity, 2000 f.-s.; striking energy, 916 ft.-tons; penetrated the plate and about 20'' of backing, breaking up. Ogive remained in backing, remainder flying out of shot hole. The right hand edge of the plate 16'' wide thrown to the ground, from the place where cracked in previous round. A new surface crack 10'' long developed to the right of No. 8. Shot hole 4¼'' to 5'' in diameter.

Board report, N. P. G., letter No. 740, Oct. 10, 1894.

No. 1 = 4'',	33 lbs.,	at 1491 ft.-s.	Into wood 12''.
" 2 = 4'',	"	" 1595 "	Penet. 1.6''.
" 3 = 4'',	"	" 1676 "	Through all.
" 4 = 4'',	"	" 1595 "	Penet. 0.9''.
" 5 = 4'',	"	" 1595 "	Penet. 1''.
" 6 = 4'',	"	" 1595 "	Penet. 1.5''.
" 7 = 4'',	"	" 1595 "	Penet. 1''.
" 8 = 4'',	"	" 2000 "	Into wood 20''.

former is extended, and hence broken. Numerous tests have been made of face hardened plates in which cracks from 0.5″ to 0.8″ deep, some as wide as 0.12″, were formed in bending the plates after cementation and before hardening. The range of temperature in which the highly carburized surface could bend without rupture being far less than in the case of the plate's back. (Several examples of plates showing cracks of this description are given.)

The chill cracks confined to the surface of certain Grüson armor plates have been tested in a most thorough manner with results similar to those obtained in the case of face hardened armor. That is, they seemed in no way whatever to weaken the plates; no cracks were initiated by them, nor did they give direction or extension to any of the fresh cracks formed by impact.

It may, of course, be asked: If it is an advantage to extend the stress of the blow over as large an area as possible by causing the depression to be wide and shallow, would not that result be prevented by cutting the surface up into small sections which would tend to localize the bending effect by shortening the arm? In reply, it may be stated that in stiff hard faced plates attacked by comparatively small calibers, the depression is so shallow that radial cracks seldom extend beyond what would be the position of the fringe in a soft plate. Also that in more elastic hard faced plates, or stiff plates attacked by large calibers, the angle of the cone is such that the brittle surface is unable to adapt itself to it in the immediate vicinity of the impact, so that both radial and concentric cracks are formed, causing flaking in no way affecting the integrity of the tough and elastic metal beneath.

Thus far, thin plates alone have been considered. In the case of thick plates, the typical failure is by cracking to an edge, then, perhaps, allowing perforation. There are a number of reasons why the thick plate is more liable to crack than the thin one. The metal displaced by the point of the projectile in thin plates crowds before it, causing a back bulge. In a thick plate there may be sufficient stiff body and back before the projectile's point to prevent this at first, forcing the metal aside about the ogival and either causing great fragments of the face to fly or splitting the plate. With the larger caliber the same slight penetration requires a much wider opening; the effect of the shell, so far as the layers are concerned, is therefore local, being more concentrated and abrupt. The only way for thick plates to avoid cracking seems to be by failing locally; that is, by possessing a weak body and back, which of course may be carried too far.

In this connection, it would be well to consider the various causes from which plates crack under impact. 1. Initial stresses, flaws, or other defects. 2. Wedging apart of the plate. 3. By bending or breaking through on the giving way of the structure behind the impact.

In certain armor plates the first shot develops important cracks while those following have comparatively little effect. Thus in the 3″ face hardened nickel steel plate No. 4 (Fig. 60/91), the first 6-pdr. shot caused a through crack from the impact at the center of the plate to the bolt hole at the left lower corner. At the same test, a 3″ all steel plate was cracked through by the first shot, after which repeated impacts produced no other cracks. Evidently these first cracks were entirely due to stresses in the plates caused by faulty tempering. These stresses being evolved by the plates cracking, subsequent impacts produce effects strictly proportional to their energies.

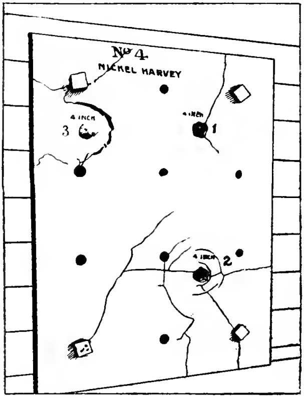


FIG. 60/91. 3-IN. PLATE NO. 4.

The impacts of the smaller projectiles are not shown.

The so-called "wedging effect" of a projectile whose caliber is large compared with the thickness of the plate, is merely the result of a combination of the uniform radiating crack or tear before described, with lines of structural weakness due to existing stresses, defects in the metal, or the proximity of an edge or old impact. In this case one or more of the otherwise incipient radial cracks open out and render the extension of the rest unnecessary. The idea that cracks run to weak points is of course absurd, they follow the weakest lines which may or may not lead towards the nearest edge or weak spot. They may start from weak spots or lines of stress, however, independent of the impact, through vibration. If, however, as in the case of a large caliber projectile, the zone of metal stretched to its elastic limit, preceding that in which cracking has occurred, both being practically concentric and circular, widens as the projectile enters until it reaches an edge or defect, the plate snaps to that point. After this the entering shot acts as a true wedge to pry apart the plate with an effort concentrated perhaps on a part of the circumference of the shot hole as yet showing no weakness whatever. A good example of this is the cracking of the Schneider all steel plate in the armor trial of 1890 under the 8-inch impact.

The 3″ plate No. 4 labored under the disadvantage of having been cemented and hardened while containing twelve 2″ through bolt holes. Yet, after shattering twenty-one 6-pdr. armor-piercing projectiles at 1804 ft. s. velocity, it stopped three 4″ 36-lb. A. P. shell, moving at velocities of 1700 ft. s. The cracks in this plate do not appear at all due to the wedging effect of the projectiles. Thus the third shot has nearly broken a large conical fragment out of the plate without cracking to or from the impact. Another shot is surrounded by concentric cracks, showing the toughness and elasticity of its backing. It will be noted that in weak backed compound plates the radiating cracks from successive impacts often cross at all angles, apparently having no effect on each other. Another peculiarity in the case of the 3″ plate is that neither the 6-pdr. impacts nor the bolt holes appeared to determine the direction of the cracks, which in fact, in all but two instances, seemed to avoid the former. Two experimental face hardened plates (Fig. 224), on the faces of which were a number of tap bolt holes, behaved in a similar manner. There is reason to believe that these plates were in a state of stress, however, and that the crack near the first impact, caused by the second shot, *started from the edge of the plate.* Cracks of this sort may generally be detected by their running by the side of the impact and not to it. Repeated impacts, of course, weaken these plates; large areas are caused to vibrate violently, and are perhaps extended or compressed, while original lines of weakness are accentuated by the natural accumulation of strains about the more sensitive points.

In considering the resistance of plates composed of layers of varying strength and elasticity, the problem is undoubtedly rendered more complicated, from a mathematical point of view, by regarding the plate as if made up of thin sheets separated by springs corresponding in strength and amplitude to the varying elasticities. Some light may be thrown on the subject, however, and the attempt will be made. In this case, the energy of the projectile should also be regarded as divided among a series of disks of molecular thickness separated by weightless springs whose play and strength correspond to the elastic compression and strength of the metal at the various points.

Should such a projectile strike a rigid, impenetrable target, the first disk delivers up its energy, which is transformed into heat, and the possible vibration or movement of the structure as a whole. It is probable that some energy is also stored in the elastic deformation of the molecules themselves. The second disk arrives with its energy diminished by that required to compress the spring before it; if there is sufficient left to overcome the molecular forces its particles may be forced over and among those of the first disk, the remainder of the energy going into heat or compressing the molecules themselves. Doubtless this transfer of energy is taking place at the same instant along a considerable length of the projectile, involving numerous disks and springs, and forming a wave of compression longer or shorter according to the strength or weakness of the springs and the velocity of the disks. The velocity of propagation of this wave determines the duration and character of the impact. A sudden stoppage of the leading members of such a system in which, through weakness of the springs, the wave of compression is very short, may cause it to be crushed in detail; crushing must occur anyway against such a target when the disks contain more energy than the springs can absorb, or may be converted into heat in the crushing together of the molecules; for it is inconceivable that two particles stored with kinetic energy could exchange that for a state of rest at a higher temperature upon the first instant of an imperfect impact. If the compression of all the springs to the minimum elastic point, plus the heat imparted to plate, projectile and the surrounding atmosphere, as well as that expended in deforming the molecules themselves, did not consume all the energy, that remaining would be employed in forcing the particles in among each other, causing a displacement in the direction of the least resistance at right angles to the line of flight. The resultant force would create a shear plane at 45° to the line of flight. The compression of the springs or molecular forces is doubtless involved with that of the molecules themselves, it has been thought advisable, however, to consider them separately on account of the purely speculative nature of the latter.

The stiffer the springs, or the higher the elastic limit of the metal, the longer the wave of compression and the greater the number of disks acting together. With a low elastic limit, the projectile would be set up or crushed in detail. If its energy be entirely stored in the compression of its springs and dissipated in heat it will rebound, perhaps in fragments, through crushing on impact.

Suppose now that the target is composed of layers held apart by springs similar in character to the projectile. It is apparent that it will require considerable more energy to compress the first plate spring than that of the projectile, on account of the extensive supporting area. The latter will, therefore, where the two are nearly matched, be in a state of full compression some time before the plate; and it will then act as a unit upon the layers of the plate in detail, more or less marked according to the latter's elastic weakness and play of springs. In this way penetration of a homogeneous plate occurs; its resistance being necessarily expended more or less in detail.

If the exterior springs in the plate are extremely stiff and have very little play, as in face hardened armor, it is apparent that a much greater compression must be exerted upon the projectile with a very slight movement of the surface layers of the plate, and if the latter's exterior is not yet wholly compressed when the projectile is, the remaining energy must be considerably diminished before penetration can occur.

In a theoretically perfect face hardened plate, the elastic limit of successive layers would be regularly lower, starting from the base of the chill and extending inward. As the extension or compression of each, within the elastic limit, would be proportional to the stress, and as the stress, being distributed over larger and larger areas, is less for each successive one, a point might be reached when every layer opposed to the advancing projectile is stretched to its elastic limit. The slightest further advance is, of course, met by a vastly increased resistance, the front layer of the plate possibly cracking and the others elongating. The projectile being fully compressed, any sudden increase in resistance will cause a more or less abrupt retardation, indicating a considerable loss of energy which, not being expended on the plate, must be done on the projectile.

It may be asked, Why would it not be better to have the entire plate of the high elastic strength of the face? If resistance to an instantaneous non-persistent impact was all that was required this might be the case, but something more is wanted, that is, the ability of the plate to hold together at least for a minute space of time. In metal of high elastic strength, the failing point is usually but little beyond the elastic limit; there is no broad range of permanent elongation before failure, so that a crack initiated at the surface would run through the plate with but a moderate increase of stress.

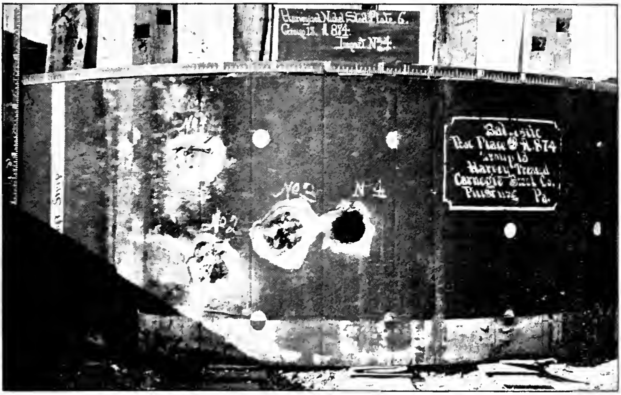
Recently a 6″ face hardened plate was perforated by 6″ projectiles of an improved type at a striking velocity of 1700 ft. s. The same plate had withstood service armor-piercing projectiles at a velocity of 2100 ft. s. This has led to the idea that, with still further improvement in projectiles, more resistance will be lost by the comparatively soft body and back of Harvey plates than will be gained by their hard face, so that a return to a homogeneous but a tougher type of plate probably of some nickel, chrome, or manganese steel alloy will be in order. This argument is fallacious. The body of Harvey plates, especially those of moderate thickness, are usually tougher than the old oil tempered plates, having about the same elongation but often considerably greater tensile strength.

In addition, while protesting full faith in a rapid advance and development of the metallurgical arts, especially now that the capacity and application of the electrical furnace has been so greatly extended, the writer fails to see that the promised alloy has yet appeared above even the experimental horizon. As under the most favorable circumstances it required three years of experimentation before service face hardened armor was sufficiently developed to be contracted for in this country, and nearly a year more before the process had been demonstrated as practicable and a success, it does not appear that the new alloy, as yet unknown even to the laboratory, is a dangerous competitor. Even should it appear, it will doubtless be as susceptible to the various processes of face hardening as its weaker predecessors which have been thus benefited.

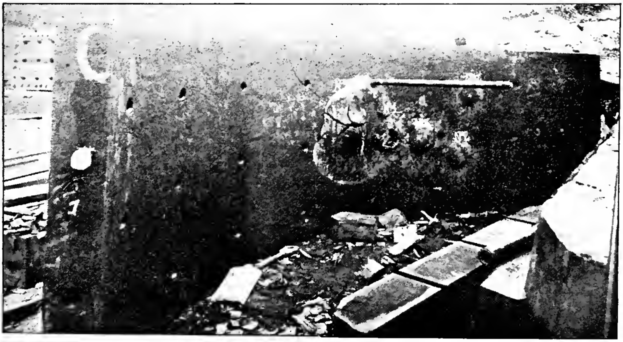
The objection to the homogeneous plate, whether water tempered or oil tempered, is that if tough rather than hard it resists in detail and through its own destruction almost as does wrought iron. If it is hard its elastic limit is near its failing point, it can stand one instantaneous impact, perhaps, but it cannot flow; there is no way of absorbing energy except in a weak fashion by cracking, and if the projectile is not destroyed perforation may ensue. It is therefore better, as the back of the plate is approached and a less and less demand made upon its elastic strength, to lower the elastic limit and increase the ductility. There is a limit to this, however, in thick plates. There is another point in this connection. Some authorities do not regard elongation as of much importance under impact; they point to the failures of car axles and mishandled boiler plates. These, despite the ductility shown in their test specimens, frequently appear, when fractured in service, sharp and even crystalline with no signs of ductility. Ductility cannot be shown unless the metal draws down. If a stress passes over a line of weakness of less resistance, as at the edge of a cooling plate, the opposing forces working on each particle in that line are balanced to the last. There does not appear to be, as in the case of a test specimen, a severe stress on the exterior and a less one on the interior, whereby the particles are given an opportunity to separate successively and flow in the direction of least resistance. Stress is applied to each individual particle, and the separation of a single pair means the separation of all.

One point more: until penetration occurs the cone of depression is intact; to resist the first penetrating effect therefore until the base of the cone is widespread is to greatly increase the resistance. The first effect of penetration in homogeneous plates is a distinct flow of metal. If that before the projectile refuses to become viscous under pressure and flow; if it lies there, for example, like granite, that may be pulverized but the particles of which will not slide over each other, an entirely new character is given the resistance of the surface of the plate. The point of the projectile must carry this intractible film before and around it. Every advance drags in more of the jagged fragments of the hardened surface, cutting and scoring ogival and plate as well, thus largely increasing the volume of metal which must be removed to permit the passage of the shot. There is a different thickness of this hard surface most suitable for every thickness of plate. Its object is to distribute the energy of the projectile; to prevent the flow of metal up and around it; to force down the plate surface and keep its resistance extended over as large an area as possible, as though bottled up and braced at the point of impact. Thus the absence of a front bulge must indicate that all of the resistance of the plate has radiated from the shot's head, and been widely distributed. The presence of a front bulge indicates a more local resistance, the displaced metal having simply eddied about the shot's head.

The idea has been expressed by some that the merest film of hardened surface is all that is necessary. This is incorrect. Service projectiles which have succeeded in piercing good face hardened plates, frequently have a considerable depth of the ogival surface fused and scraped off. As the head of the projectile enters there is opposed to each zone of the surface of the ogival the resistance of strata of varying hardness and elasticity, the largest at any one instant being that of the hardened surface. Should this be a mere film, its peculiar effect would be hardly appreciable, although the varying characteristics of the strata below would permit the plate to concentrate its resistance and give a good account of itself.



No. 239.—Impact No. 4. Test of 6-in curved face hardened nickel steel plate A—874, group 13, Carnegie Steel Co. Carpenter special 6-in. A P. shell, No. 925, lot 7. Striking velocity, 2110 f.-s. Shell much broken; penetrated plate entirely, lodging in backing. No cracks in plate. Hardened surface scaled around impact. N. P. G., letter No. 282, April 3, 1894.
See No. 243a, below, for other impacts.



No. 243a—Back of 6-in. face hardened nickel steel plate A—874, group 13, Carnegie Steel Co., showing the back bulges of 6-in. impacts Nos. 1, 2, 3 and 4, and 8-in. impact No. 5; the striking velocities being 1472 f.-s., 1659 f.-s., 1975 f.-s., and 2110 f.-s. for the 6-in., and 1472 f.-s for the 8-in. N. P. G., letter No. 314, April 13, 1894.

Impact No. 1 = 6″; 100 lbs. at 1472 ft.-s. = 1504 ft.-tons.
" " 2 = 6″; " " 1659 " = 1910 "
" " 3 = 6″; " " 1975 " = 2707 "
" " 4 = 6″; " " 2110 " = 3090 "
" " 5 = 8″; 250 lbs. " 1472 " = 3754 "

It is found that when projectiles large in caliber compared with the thickness of a face hardened plate most nearly match it, the head enters until its bourrelet is clear of the intact hard surface when it breaks out a dome-shaped back bulge, to which its head remains welded, while the body and base are crushed and thrown to the front. In most cases, a few feet less velocity will make the difference between complete perforation and the bare clearance of the hard surface by the shoulder of the projectile. The crushing of the latter in such a case naturally takes place at the instant maximum resistance is offered; that is, when the crumbling, expanding zone of hard metal about the ogival is most depressed and strongly and extensively supported by the under layers.

The subject of caliber in the attack of face hardened plates is important. The question may be asked, Would a face hardened plate, barely capable of resisting a certain caliber of projectile, be unable to resist a larger caliber having no greater energy?

The area of zones in the ogivals of the projectiles exposed to like resistance in the two instances vary as the calibers, but the sections of the projectiles along the planes of greatest weakness vary as the squares of the calibers. The larger caliber would, for this reason alone, inflict more damage on the plate before being broken up. Also, as its energy consists in a much larger degree of indestructible, or at least less easily diverted mass, and less of velocity, it would produce an equal amount of damage upon the plate with a proportionately smaller loss of velocity than the smaller caliber. From this it is evident that of the two projectiles the lighter, with less resistance to crushing, has its velocity diminished much more suddenly and violently than the larger caliber with broader planes of resistance. It would therefore appear that when the target is superior to the gun, and as the vast majority of impacts in action will be oblique where this will be the case, the larger the caliber, even with the same energy, the greater the damage inflicted. The introduction of armor of increased resistance is certain therefore to bring about an increase in the calibers of the guns.

On the other hand, when plate and target are about evenly matched, the larger caliber must break away a greater volume of the plate before perforation, this volume varying as the squares of the calibers. The resistance of the plate as a whole is also more certain to be felt against the slow moving projectile. Again, the larger ogival tends to concentrate its attack on each successive strata more than the smaller one; that is, it breaks away as much of the hard face as the latter with but a fraction of its penetration, so that if there should be a plane of weakness or inferior strata, there would be greater danger of breaking the plate up in detail. This is seen in the attack of laminated or piped plates by large calibers, when the back bulge is broken out in slabs.

ADDITIONAL NOTES AND CORRECTIONS.

With the ultimate object of correctness in the paper, Lieutenant Ackerman submitted the following additional notes, giving credit when due.* They were submitted after the discussion.

At the end of the first paragraph, page 8:—It has been suggested, for example, that the gas check disks referred to, having been cut from round bars were suffering from radial forging strains; had they been "upset" before being machined and tempered, or subjected to a long annealing, they would have tempered without difficulty.

At the bottom of page 20:—This paragraph is, as Mr. Howe states in the discussion, incomprehensible. It should read "The lime probably took up moisture from the air, becoming slaked, while the charcoal absorbed oxygen."

In regard to the foot note on page 21, CuO should be Cu_2O. See criticism by Mr. Howe.

After "constraint" in the middle of page 29:—This statement needs a generous qualification; chemical affinity is potential energy, it can exert stress only as a result of its satisfaction as indicated in the following paragraph. See discussion.

After the last complete paragraph on page 29:—This statement is incorrect; change of carbon from the "cement" to the "hardening" form is dependent only upon the temperature.

After "hardness," line 4, page 30:—This refers to hardening for *tempering*. See Howe, Metallurgy of Steel, page 22, §39.

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* Three engravings used in the printing were kindly lent to the Institute by Mr. W. H. Jaques, having been used in his article in the *Engineering Magazine*.

After "elasticity", line 4, page 33:—This statement should be qualified so far as the words "*largely* increased" are concerned. It is found that the exterior film of a hardened cylinder is more dense than the interior. Also that the modulus varies nearly with the seven-thirds power of the density. See discussion.

After "plate," line 3, page 35:—That is, the plate would be affected to a greater depth.

"Ackerman," line 2 from bottom of page 35 should be "Akerman."

After "fluid," line 2, page 37:—This statement should be materially qualified. There is considerable expansion before the melting point is reached, although at that point the metal is more dense than at 1200° F.

After "This evolution", line 4, page 37:—This reference is believed to be incorrect; it is not essential, however, to the argument.

After last complete paragraph, page 37:—Professor Abel's experiments indicate that the condition of the carbon is hardly changed in wire drawing. This, however, is not essential, it is known that by forging through the critical point some carbon is retained in the "hardening" form; my contention is that pressure exerted at that time has the same effect. See Howe in discussion.

After line 22, page 39:—This apparent contradiction of views between Messrs. Brustlein and Howe is due to an error of my own. They are both correct. The former refers to the effect of varying percentages of carbon. The latter to the effect of *treatment* in steel containing any particular percentage of carbon.

On page 5, 11th line from the bottom:—"A 28 per cent. carbon plate" should read "A .28 per cent. carbon plate." Page 16, third line, "Roma shoals" should read "Romer shoals." Page 18, seven lines from bottom, "25 per cent." should read .25 per cent. Page 45, line 4 from top, "90° cone" should read "45° cone."

DISCUSSION.

Mr. WM. ALLEN SMITH.*—I expected to have sent you before this some remarks on the chronology and details of the negotiations between the late Mr. Harvey and the Naval Ordnance Bureau, but I have been laid up with an attack of grippe, and have been so pressed with other matters that I have not been able to get into shape the criticism of your paper which you asked for. I may, however, remark, that on page 5 it appears to us you give rather more credit to the Navy Department than is quite just, in view of the fact that Mr. Harvey had perfectly well defined views of what he wanted to accomplish before he saw Commodore Folger; and really by his presentation of his views so interested Commodore Folger as to induce the Commodore to recommend the experiments by the Navy Department which were subsequently made, and which showed the correctness of Mr. Harvey's views as to the best method of making a perfect armor plate.

We would also remark that we do not know and do not believe that what Mr. John D. Ellis did, in respect to applying the process of cementation to armor plate, amounted to anything more than a crude, abortive, and abandoned experiment; and in view of the fact that Mr. Ellis did nothing more than employ the ordinary cementation process, it is going rather too far to describe what he did as the "Ellis Process."

In the second paragraph on page 8, there is a slight error concerning the Schneider plate, which, as a matter of fact, was both super-carburized and hardened at the Washington Navy Yard, and was tested in February, 1891.

The erection at the Washington Navy Yard of the furnace for treating this Schneider plate was begun in November, 1890. These matters of dates are of course of minor importance. But it seems desirable to mention that Mr. Harvey, early in his negotiations with the Navy Department, and in support of his views, exhibited to Commodore Folger a block of steel, one side of which had been treated by his process, and had been made so hard that it could not be indented by a center punch driven by a sledge hammer. The exhibition of this small block of steel to Commodore Folger preceded the completion of the arrangement by which the original 6-inch plate was sent to Newark to be Harveyed.

I will only add that your contribution to the literature of face hardened armor is both valuable and timely.

Mr. H. M. HOWE, Boston, Mass.—We must thank the author for a great deal of very valuable information which he gives as to the actual procedure in Harveying and hardening armor, and for his interesting and suggestive propositions. As a metallurgist I must compliment him on the

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*Discussion addressed to author.

amount of very recently published information with which he has familiarized himself on the exceedingly difficult and complex question of the hardening of steel. So difficult is this question, however, that there are some points on which I can perhaps set him right, and others as to which I should be glad to learn his authority: and so it is with the question of Harveying. Let me touch on these before taking up his main contention that gashing should increase resistance.

Cementation.—On page 21, line 6 and foot-note, the author, while correctly asserting that the phosphoric acid of bone-charcoal is not reduced in cementation, yet thinks that its phosphorus acts as a deoxidizing agent, as phosphorus does in reducing copper-oxide in making phosphor-bronze (by the way, it is cuprous oxide, Cu_2O, that the phosphorus in this case reduces, not cupric oxide, CuO, as the author says). This must be a slip of the pen. The unreduced phosphoric acid of the bone-charcoal, a fully oxidized compound, of course cannot take up more oxygen, and hence cannot deoxidize any other substance. In making phosphor bronze we use, not phosphoric acid, but phosphorus in an unoxidized and hence an oxygen-taking form.

On the same page, line 17, what is his authority for the assertion that cold iron buried in charcoal absorbs carbon even without the aid of heat? This must be an error.

Why quote, on page 20, line 26, "Dannemora iron" (by the way, one of the brands of iron especially noted for its freedom from phosphorus), "gives out an odor of P when twisted at a red heat?" Such an assertion is incomprehensible.

The same page, the last three lines. "The highly oxidized lime" (I had supposed that lime was a perfectly definite oxide of calcium, and that all lime was equally oxidized), probably took up moisture by selection of H from the air" (but whence is to come the oxygen which, uniting with that hydrogen, could form that moisture? surely this cannot be serious) "as well as C from the carbon present in the charcoal." What kind of compound was then formed between lime, water and carbon? A hydrated oxycarbide of calcium? To form lime-carbonate we need oxygen, not hydrogen.

Page 21, line 31. "On heating, the carbon is expelled from the limestone and unites with the oxygen . . . above." Can it be necessary to explain that, when limestone is heated, not carbon but carbonic acid is liberated?

Page 22, lines 4 to 14. "Soda ash frees the metal (iron) of oxygen." That soda ash, carbonate of soda, an already fully oxidized substance, is further to take up from solid iron with which it is in contact the oxygen which that iron does not contain, does not call for much comment. "The calcined lime eliminates the oxygen . . . in the retort." Here again, a fully oxidized stable substance, lime, is to take up oxygen. "Pure cyanogen-gas is generated, which permeates the metal, carrying with it the free tungstic acid which tends to give the metal greater hardness." Without further explanation or evidence, we must regard this as unworthy of serious attention. Tungstic acid (anhydride) is not volatile. When heated as here with charcoal, it is reduced to metallic tungsten and tungsten dioxide. Tungsten volatilizes at about 3400° F. (1900° C.). But if tungstic acid were carried into the metal as here asserted, what good would it do? It is not tungstic acid, but metallic tungsten that hardens steel.

On page 23, the last four lines, the author says that it seems that in Harveying iron and carbon both volatilize, "when of course the formation of a definite carbide would naturally follow." Carbon has the power of migrating through hot plastic iron, and in Dr. Fleitmann's experiments, to which the author refers, it was reported that iron had the power of migrating in hot plastic nickel. Later experiments have shown that lithium can migrate in hot plastic sodium-silicate glass. These migrations in plastic substances are extremely interesting and instructive: they remind us of crystallization in like masses; but they do not imply, they hardly suggest volatilization. It is in the highest degree improbable that either iron or carbon volatilizes as such in case-hardening or Harveying. Nor, if they did volatilize, would it at all follow as the author asserts that "the formation of a definite carbide would naturally result."

On page 26, line 3, the author asserts that iron contracts in heating from 1832° F. (1000° C.) to the melting-point; on page 37, line 1, that it contracts in heating from 1200° F. (649° C.) to the melting-point; and in line 4, that the recalescence is accompanied by contraction. In each respect he is completely and curiously mistaken. Indeed, the contraction of iron in cooling from bright redness down to the recalescence-point, and its expansion at that point, are notorious, and if I remember aright, are what led to the discovery by Gore of the recalescence.* The enormous shrinkage which occurs in the early part of the cooling of steel castings, and which is one of the chief stumbling blocks in their manufacture, the like contraction of steel ingots, of rails, plates and other products in cooling are so well known and such obvious contradictions of the author's assertions, that one fancies that this must be a case of heterophasia, of saying the very opposite of what is intended. See page 109, J. I. S., 1891.

On page 37, four lines from the bottom, he seems to quote, as an explanation of the increase of strength of steel caused by wire-drawing, that the pressure which accompanies it forces the carbon into combination, by which he must mean, forces it into the hardening state, because most, and usually all, of the carbon in steel is in any case combined. Now, as wire-drawing causes like strengthening effects not only in the softest iron and steel, the freest possible from carbon, but also in all other malleable metals

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* Outlines of the history of this matter, together with many references, are given on pages 187 and 188 of my "Metallurgy of Steel."

and alloys so far as we know, it would not be reasonable to suppose that the like effect in case of steel is chiefly due to so unlike a cause as forcing into combination the carbon which these other substances lack. But, quite apart from the extreme unreasonableness of such a supposition, we have Abel's experiments showing that these cold-working operations do not transfer the carbon to the hardening state.*

While the reactions on pages 24 and 25 by which the author explains the chemistry of cementation may be true, yet I believe that the operation is far more clearly explained by two well-known, simple, fundamental reactions,

$$2CO = C + CO_2,$$

by which carbon is deposited within the metal, where its absorption needs no explanation, and

$$CO_2 + C = 2CO,$$

by which the resulting carbonic acid renews the supply of carbonic oxide, and thus enables a small quantity of oxygen initially present to transport an indefinite quantity of carbon into the iron. This transportation of the carbon from the charcoal into the iron is all that needs explaining. There may be other intermediate and side reactions, but these which I have just given seem to be the end-reactions which suffice to explain the whole clearly. Oxidation of iron may occur as Lieutenant Ackerman supposes, but if so, it appears to be only an intermediate reaction, which serves rather to confuse than to clarify matters. For example, his deduction that there is an exhaustion of oxygen which must stop the operation seems to spring from this, and is probably misleading.

Hardening.—The third paragraph of page 29 argues that the smaller density of hardened than of unhardened steel in itself implies stress. Stress there no doubt is in hardened steel ; but we infer it from other evidence. The mere lightness as such might be readily explained by difference in chemical constitution. In the following sentences he seems to think that unsatisfied chemical affinity may create stress ; this seems to be a confusion of ideas, or a misuse of words.

Immediately below, and also in the last three lines of page 34, he naturally mistakes the results of Professor Langley's experiments. These showed that quenching steel, even from as low a temperature as 108° C. lightened it somewhat. They have been repeatedly quoted as proving hardening. But they merely showed that this quenching made the metal slightly lighter. No measure of hardness was attempted, nor have I ever seen any reason to believe that the metal was made in the least harder.

Near the end of page 29 he says that the hardening tendency is said to be proportional to the duration of the temperature of hardening. I have never heard this suggested before. So far as my observation goes, all the evidence tends to show that when steel is raised to a given tempera-

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* Trans. Institution Mechanical Engineers, 1881, page 703.

ture, measurably above the critical point, W, the degree of hardening is practically independent of the length of time that the steel is held there. In other words, the change from cement to hardening carbon seems to take place with very great rapidity. No considerable length of time is needed to complete it.

On page 39, lines 10 and 11, the author falls into the curious error of supposing that manganese steel forges particularly well and "welds with great facility." Would that it did! Unusual precautions are required in forging it; even after these have been discovered and adopted, forging it is no easy matter, and as for welding it, why nobody thus far has succeeded in welding it properly so far as I know, even with great experience in electric welding.

From among the assertions which the author makes or quotes, some of which I fear must be wrong, I select the following, to ask him to give us his authority.

Page 27, line 7. "That steel of low tenacity carburizes with greater ease than other steel" (this is as I understand him).

Page 27, line 5. "It is said that the porosity of steel is generally in an inverse ratio to its tensile strength."

What is the porosity of steel, and how does one determine it? Speaking broadly, the density of steel is inversely as its tenacity. If we were to draw any inference from this as to porosity (and I for one should not dare to), it would be that the porosity, which should if anything be inversely as the density, should be directly as the tenacity, and not inversely as the author has it.

Page 33, lines 1 to 4. He asserts that water-quenching highly-carburized metal *greatly increases* the modulus of elasticity. Such evidence as I have met agrees with his previous and opposing assertion (page 32, line 26), that water-quenching has little effect on the modulus. The high tenacity, 400,000 pounds per square inch, which he quotes apparently as indicating an increase of the modulus, is no more evidence as to the modulus than the weight of a book is as to the weight of its author. The detailed information as to the modulus implied on this page should be of great value.

Page 30, line 3. "The more slowly the metal is heated to the higher temperature, the tougher it becomes without loss of hardness; this toughness increasing with the the length of time of exposure to that temperature." I can recall no evidence even pointing in this direction.

Page 34, seventh line from the bottom. An unqualified assertion that "Both the tensile strength and *ductility* of the mildest steels are greatly *increased* by quenching." My own extensive tests* had showed that quenching from above the critical point greatly *lessens the ductility* of all the steels which I tested, including one with 0.09 per cent. of carbon,

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* "The Heat Treatment of Steel." Trans. Am. Inst. Mining Engineers, XXIII., p. 466, and especially p. 531.

which is certainly among "the mildest steels." There are some things which suggest that quenching from *below* the critical points, below which no true hardening occurs, may increase the ductility. This does not, however, help the author at all, who from the context evidently refers to quenching from above the critical point. He must have some full data of which I am ignorant, unless, as I fear, he is completely mistaken.

On page 35, line 1, as an inference from the assertion on which I have just commented, he further asserts: "It is evident, therefore, that the more sudden and complete the chill, the greater the increase of toughness in the body and back of the plate." As the context shows that toughness here means ductility, his conclusion seems to me not only far from evident, but in the very highest degree improbable.

To the same apparent error I ascribe his mistake on page 32, lines 19 to 25, that, save at the very surface, the plate is decrementally *toughened*, not decrementally *hardened*. Here he appears to be completely in error.

On page 8, line 6, he says that doubtless deleterious components are volatilized in the Harvey process from inferior metal. The volatilization of sulphur has been observed under like conditions; but has that of any other deleterious component?

On page 37, line 2, he quotes the specific gravity of molten steel as 8.05. This is surprisingly if not improbably high.

Let us now consider the author's main contention that gashing the face of a plate will

(1) Cause it to heat more quickly, and

(2) To carburize more quickly, thus saving time in Harveying;

(3) By increasing the pressure on the face of the plate will increase the degree of hardening for a given temperature, thus permitting the use of a lower quenching temperature, and finally, thus leading to less severe stresses within the plate; and

(4) Will increase the resistance to penetration. Let us consider these separately.

A plane parallel with the face of the plate, and slightly below its surface so as to lie just tangent to the bottoms or troughs of these gashes, divides the plate into two parts, a solid unbroken part, quite like the whole of any ungashed plate, and a lot of ridges or other elevations rising from this solid part, consisting of the steel left between the gashes. According to the direction of the gashes, these elevations may be true ridges or simply peaks; if the gashes are far apart, the ridges become table-lands. But, whatever their shape, let us for simplicity call this part of the plate above the bottom of the gashes the "ridge" part, and that below their bottom the "body" part.

1. *Heat Absorption.*—We may concede that the existence of a properly proportioned ridge part between the body part and the source of heat might hasten the heating of the body part, because the greater surface of

the ridges would absorb heat more quickly, and because the high conductivity of the metal would quickly transfer into the plate any heat taken up by the ridges.

But it seems to me that the saving of time and fuel, while it might exist, would be inconsiderable,—so slight as to be wholly unimportant.

2. While the increase of surface due to gashing would cause more carbon to be taken up per hour by the plate as a whole, yet this excess would, I believe, be found in the ridge part. The ridge part would retard the carburizing of the body part, because all the carbon which reaches the body must now pass through the ridge part, save what little enters at the bottoms of the troughs between the ridges. The case is wholly different from that of the mere introduction of heat. In the latter case, the fact that the ridge part separates the body part from the source of heat may well be outweighed by the high thermal conductivity of the metal, which would transfer into the plate with extreme rapidity the increased quantity of heat which its increased surface led it to absorb. Not so with the carburizing gases, however. The ridge part would, in effect, stand as an irregular barrier to the carburizing action, which would have to reach the body through the ridge part, and therefore much more slowly. We must remember that, while heat passes by conduction through iron quicker than through air or through the atmosphere which bathes the plate, yet the reverse is probably true of the carburizing action.

3. While there is much to suggest that pressure increases the degree of hardening caused by any given quenching, I see no reason to believe that it plays an important part. But, if it did, then it seems to me that the author's gashes should have exactly the opposite effect from what he supposes, and should lessen rather than increase the pressure.

When a plate is quenched, its skin presses on its interior because the skin cools faster, and hence contracts faster than the interior. This of course at first throws the skin into tension, the interior into compression. The pressure of the skin on the inside may be likened to the tightening of a strap. A gashed skin is like a crimped strap, with corrugations transverse to its length. Clearly, for given shortening an initially crimped strap will press less tightly than one initially straight. So, it seems to me, that, for given contraction, a gashed skin must press less strongly on the underlying parts than an initially straight, smooth skin.

Gashing might oppose flaking. The surfaces of least cohesion should, in a gashed plate, be roughly parallel with the gashed surface, because the variation both in carburizing and in hardening would run roughly parallel with it; and such irregular surfaces would be less likely than plane ones to coincide with the surfaces of high stress.

4. Whether because of, or in spite of my ignorance of resistance to penetration, the argument that it should be increased by gashing seems to me utterly fallacious.

First, let us recognize clearly that, besides increasing the hardness proper, Harveying and quenching also increase enormously the compressive strength and tenacity, and their resultant, transverse strength, all beneficial, and also brittleness, a most injurious property. Hardness proper and compressive strength, both composite quantities, with many elements in common, are yet distinct. Chilled cast iron and quartz, each at least as hard as hardened steel, have little compressive strength and little tenacity under impact. I believe that the author makes a capital mistake in confining his attention unduly to hardness proper, which I believe aids penetrative resistance but little, and neglecting the transverse, compressive, and tensile strength, which I believe are the main components of resistance. The brittleness which accompanies these beneficial effects of hardening, of course, as such, lessens resistance.

Let us resolve the resistance which a hard face offers to penetration into what I suppose must be two of its chief components, (1) normal resistance parallel with the axis of the projectile, and (2) *radial* resistance which the face offers to being driven parallel with itself, radially away from the point of impact, as the ogive progressively forces its way farther and farther into the plate, and stretches the hole out wider and wider.

The normal resistance is like the support of a snowshoe, or of thin ice on a pond; it arises from transverse strength. The gashes are equivalent to corrugating snow and snowshoe, or ice; in either of these cases we may admit that corrugation might increase the transverse strength, and that the normal resistance of a gashed, *i. e.*, corrugated half-inch thickness of face, reckoning from the crest of the ridges to half-inch below the troughs of the gashes, might be greater than that of a plane half-inch. This means that the normal resistance of a 10-inch plate with ½-inch gashes might be greater than that of a 9.5-inch ungashed plate; but I do not see clearly that it should be as great as that of a 10-inch ungashed plate.

But when we come to radial resistance the case is far worse. The isolation and the consequent exaggerated rate of cooling of the ridges would, indeed, give them increased compressive strength, but also increased brittleness. This isolation, the presence of these gashes between the ridges, must, however, deprive them of lateral support, and must thus affect most unfavorably both these effects of the exaggerated hardening. For on the one hand it makes their compressive strength useless for radial resistance, just as a weak foundation makes the strength of a strong column useless; while on the other hand it must, I fear, make their brittleness all the more damaging. Thus I fear that, as regards radial resistance, the ridges approach the condition of grains of sand or emery, hard but useless, attached to the body of the plate.

The hardening, and hence the tensile, compressive and transverse strength of the body part, are of course greatly lessened by the retarded cooling which the interposition of the ridge part between it and the water causes. Thus the gashing in effect concentrates both the beneficial and the harmful effects of hardening, the strength and the brittleness, into the ridges, where the beneficial ones are inoperative and the harmful one is more noxious. This, it seems to me, is likely to outweigh enormously any supposed gain in normal resistance; and I fear that a 10-inch plate with half-inch gashes would be much weaker than a 9.5-inch ungashed plate, as well as far more costly. One may not prophecy in such complex questions; but these considerations seem to me to deprive the proposition of all promise.

Lieutenant W. IRVING CHAMBERS, U. S. N:—I have found Lieutenant Ackerman's valuable contribution to the literature of armor very interesting and instructive, and I can only hope to add to its interest by a few remarks concerning the process briefly alluded to in the second paragraph on page 41. This is known as the Chase-Gantt process and was discovered at the Midvale Steel Works, Philadelphia.

The fact that the best, if not all, of the modern armor-piercing projectiles are made of chrome steel is good evidence concerning the shock resisting properties of that metal and the capacity of that metal for being worked and treated under the hammer or in the oil bath and annealing furnace. Although chromium has given the best results in their armor plates, so far, the patents of these gentlemen cover the use of manganese, tungsten or any other element or alloy they may choose to employ in their special way. However, the metal of their entire plate is not strictly "chrome steel" and it is well to note that this is *chrome faced* steel only. The discovery of a comparatively cheap and simple method of introducing chromium and carbon together into the face of a plate *by absorption*, during the process of casting, marks a new and distinct era in the treatment of steel by alloys.

The bed of the mould is simply prepared with the desired alloy and baked to sufficient hardness and then the molten metal, nickel steel or steel of any desired grade, is quickly poured, as in a simple casting, leaving one or more heavy risers to feed the shrinkage as it slowly cools.

In this easy "method of cementation" the molten metal fuses the alloy, the chromium rapidly penetrates the lower face and, on account of its great affinity for carbon, carries the latter with it to a depth which is readily regulated by certain details in the process. It is supposed that the best results will obtain from a depth of hardness equal to about one-fifth the thickness of the plate. After casting, the plate is oil tempered and annealed as often as desirable and the face is then water hardened as with the Harveyed plates. The interior "pockets," which Lieutenant Ackerman shows to be so important, are always formed in this case by the hooks or projections of the hardened part which penetrate the softer part during the process of casting, or while the carbonized chromium alloy is penetrating the molten mass.

These desirable hooks thus formed are, of course, unevenly distributed.

They may, however, be readily accentuated, regulated, or produced in any desired form, square or otherwise, in the interior, by suitably preparing and placing the alloy in the mould with that end in view, and the face of the plate after casting will be perfectly smooth.

Such a plate, with a homogeneous soft back of mild steel evenly graded in toughness to a hardened surface that cannot be touched by a specially hard tool-steel center punch, seems to approach the theoretical condition mentioned on page 64. However, as Lieutenant Ackerman says, it is possible to have the back too weak to satisfy the desired conditions, but if the simple cast steel of the Chase-Gantt plate be found too weak, it can be forged or rolled down to any desired extent. For example, one of these plates, cast 11 inches thick with a hardened face about 2 inches deep, was heated and forged down to 6½ inches thickness; a piece of this was then heated and rolled down to one-half inch thickness, in which condition the hardened face was found to have been reduced almost proportionately, *i. e.*, the final thickness of the hard face was about one-eight of an inch.

The patentees of this process think that they will be able to produce results equivalent to the best service armor in plates simply cast, of the same thickness, without forging; *i. e.*, through the quality of the cast and the invisible kneading that occurs during the oil tempering and annealing processes. Of course we hope they may, but I am not so sanguine about such a marvelous achievement. It seems certain, however, that they are able to produce a greatly increased depth of hard carbonized surface in conjunction with a wonderfully tough and homogeneous back. There is, apparently, no difficulty in casting a plate thirty or more inches thick with a hardened face from three to six inches thick, and in forging or rolling this plate down to ten inches thick with a hardened face from one to two inches thick. It is also, apparently, easier to produce uniformity of results in thick plates than in thin ones.

In consideration of the valuable experience gained during the development of our present service armor and of the relative simplicity and cheapness of this rival, I anticipate a speedy development of chrome-faced armor and a considerable increase in its resisting power over that of the present service armor.

Lieutenant C. A. STONE, U. S. N:—I have read, with much interest, Lieutenant A. A. Ackerman's paper on face hardened armor, and I consider it a most valuable contribution, and one which brings together, in an able manner, the recent results on this subject with most interesting explanations. I would like to see Lieutenant Ackerman's proposed armor plate made and tried, and I hope this will soon be done. Lieutenant Ackerman's explanation of the resistance offered by the Harveyed plate by being elastically dished under the impact of the shell, is very interesting. The resistance which a plate would thus offer would appear to be similar to that offered by a circular disc when loaded at the center and supported around its circumference; a mathematical expression for this I have never seen.

On page 52 are given the results of the trial of 4″ shell against a 3″ Harvey plate with a velocity of 600 f. s; no penetration was attained and the shell were smashed. The result was caused by the resistance of the plate to being dished elastically. From this it would appear that, for a certain velocity, that resistance is sufficient to demolish the shell. I remember seeing at the Washington Navy Yard, some years ago, a plate which had spiral springs behind it, which had been fired at. Several large holes through the plate indicated the result. I do not know who was the author of this experiment. In this case the springs would offer but little resistance, and the inertia of the plate would allow it to be penetrated before the springs could do much work, even were they stiffer. In the case of the thin Harvey armor plate, the resistance it offers under impact to being elastically dished is very great; the plate, in the neighborhood of point of impact, being a most powerful spring. Thick Harvey plates will dish elastically less than the thin ones, of course, as the carbonized and tempered part is a less portion of their thickness and mass; for this, among other reasons, thick Harvey plates will be relatively more easily penetrated than the thinner ones.

Lieutenant Ackerman has not said much about the effect of the long continued high temperature of carbonization on the body of the thick plates. This tends to undo, to a great extent, the good effect of the previous forging, tending to render the body of the plate crystalline. Experiments are being made for the purpose of determining the effect of additional forging after carbonization and before tempering. A 14″ plate in which this was tried is now awaiting ballistic test.

On pages 39 and 41 of Mr. Ackerman's paper mention is made of nickel chrome and of nickel manganese Harvey plates.

If the additional forging after carbonization should not prove sufficiently successful in the case of the thick nickel steel Harvey plates, it appears to be probable that better results may be attained by the addition of chromium or manganese.

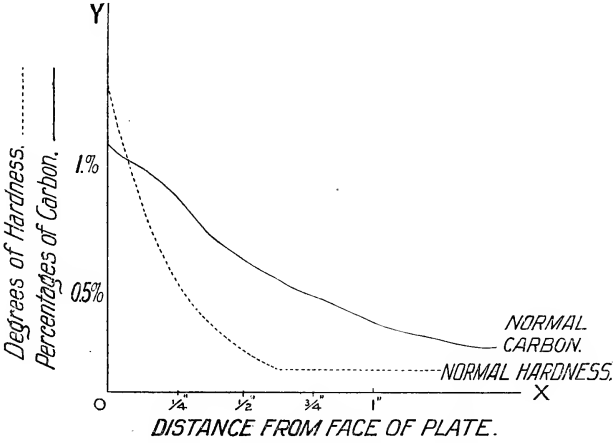
On page 33 of Mr. Ackerman's paper, it is stated that at a certain point beneath the surface of a face hardened plate, etc., the original modulus may be found.

I think that experience shows that ordinarily the carbonization extends to a greater depth into the plate than is of any use with our present means of tempering. This leaves behind the tempered face a stratum of metal higher in carbon than is desired. With our present methods of carbonization, to obtain the required amount of carbon near the surface, this unnecessary and objectionable depth of carbonization appears to be unavoidable. Experiments upon this point are much needed, but the ballistic test is the only means of determining with any certainty what results have been obtained. This is, of course, expensive and also very often not decisive, the result being due to other causes than those the effect of which we seek to determine.

The percentage of carbon, at different depths from the face of a carbonized plate, is determined by chemical analysis at each one-sixteenth of an inch of depth, until the normal amount of carbon is reached; this is at a depth of an inch and a quarter or an inch and a half, usually. These percentages of carbon may, of course, be laid off as ordinates on any convenient scale, the abscissas being the distances from the face of the plate at which these percentages occur. A curve drawn through the ends of these ordinates will give, for any case, what we may call the curve of carbon for that plate.

With our present method of tempering, the chill only reaches a depth of about five-eights of an inch; all parts of the plate to this depth are more or less tempered; the amount of tempering at any point would evidently depend, the tempering means being the same, on the amount of tempering carbon at that point, and the effectiveness of the chill, which depends probably on some function of the depth.

If we had some recognized method of determining hardness, we could, together with carbon determinations in a plate, make hardness determinations at the corresponding depths. These degrees of hardness could be laid off as ordinates on the same figure as that showing the curve of carbon, and if a curve were drawn through the ends of those new ordinates,



it could be called the curve of hardness. This latter curve would become parallel to the axis of abscissas at a point about five-eighths of an inch from the origin, the curve of carbons becoming parallel to this axis at a distance of an inch and a quarter or an inch and a half from the origin.

A comparison of these two curves would show the relation which exists between the amount of carbon and the degree of hardness obtained by the tempering, at the different depths, and, if this comparison were made for a number of plates, it is probable that information would be obtained therefrom which would be of much use in the manufacture of Harveyed armor plates. A sketch is enclosed to illustrate these curves, the full line being the curve of carbon, and the dotted line the imaginary curve of hardness.

Lieutenant ACKERMAN, U. S. N.:—I have much for which to thank the gentlemen who have discussed this paper. Few practical or business men care to correct or elucidate views which may benefit their possible competitors; others will not venture into the realm of conjecture where the disclosures of a few months to come may confute the expressed opinions of to-day.

I appreciate all the more then the honor which Mr. Howe with his great wealth of experience has done me in criticizing the paper at such length. He has pointed out errors in it which shall be frankly admitted and called attention to statements which require substantiation. He has also made certain other strictures in which I can follow him neither in logic nor in fact. However, I am assured of this, the careful reader will be able to find no error or doubtful statement in this essay which is any more necessary to the line of argument in favor of the proposed new armor plate, than a fungus is essential to the existence of the tree in which it lives.

Mr. Howe's disgust at the peculiar assortment of patent claims for various processes of cementation would be amusing were it not for the fact that he appears to hold me responsible for the errors which they contain. These claims were quoted as an interesting exhibition of the peculiar views held of the process of cementation by certain practical minds. It is expressly stated at the foot of page 22 with regard to them, that few explanations are satisfactory, while many claims are based on unsustainable assumptions.

Erroneous as they are, however, in theory, they will doubtless convey suggestions to some who it is to be hoped will discern the soul of good that lies mingled in their evil.

Exception must also be taken to the frequency with which Mr. Howe declares express quotations which occur in the essay to be assertions, thus apparently attempting to force me to defend a position where I would be at a disadvantage, and in which in every instance noted I have no real interest at stake, especially when the matter is correctly stated at length elsewhere in the essay. I refer, for example, to his criticism of the quotation on page 37 of W. Hempel's explanation of the increased strength obtained in wire drawing and cold hammering; also the remarks ascribed to Professor Barrett on the same page, that recalescence is accompanied by a contraction; also the first sentence on page 37, that metal becomes more and more dense when heated above 1200° F., until fluid. No assertion was made in these cases, in fact the words "it is said"—were used as disavowing any assumption of responsibility. The behavior of the metal at the critical points is fully explained on page 25.

Should his valuable work on the Metallurgy of Steel be read in this spirit, it would lead to endless contradictions.

For instance, on page 18 of that work this statement appears with regard to the effects of hardening, "It is said to raise the modulus of elasticity." This view of the effect of hardening on the modulus he contests in his criticism of my paper, if it was an assertion in his book, he is now in contradiction; if it was not an assertion, then many of his criticisms of this article cannot have been seriously intended.

The metallurgical premises of the essay which are criticized in the discussion may be grouped under the following heads:

1. That at the extremely high temperature employed in the Harvey process, *i. e.*, above that of molten cast iron, the gases of cementation are not only extremely attenuated, but the capacity of the metal for them is less than at a somewhat lower temperature when the metal is less dense. [No denial is made of the statement that at this high temperature much of the carbon introduced is graphitic or uncombined, unable to assist in increasing the hardness in the subsequent quenching, and to the presence of which in fact the softness and weakness of the metal after cementation is in a great measure due. This intrusion of graphite occurs to a certain but far less extent even at the ordinary temperature of cementation, for it is well known that an analysis of cement steel taken after forging will give a greater percentage of combined carbon than if taken immediately after cementation. Lieutenant Stone has called attention to this fact in his remarks. It may be added that the Carnegie Steel Company had experienced some difficulty in obtaining the requisite hardness on the face of some very thick plates cemented at a high temperature; analyses showed a fair amount of carburization, but in addition, considerable graphite, which undoubtedly weakened the surface. One of these plates was forged slightly thinner, when the analysis exhibited a quite marked *increase* of combined carbon. Upon ballistic test, the plate showed far greater resistance than any other plate of equal thickness that has yet been tested.]

Under this head also come the objections made to the "volatilization" of iron at the ordinary temperature of cementation; the connection of cementation with porosity and porosity with tensile strength; and the increase of the density of steel when heated to a temperature approximating to the melting-point. Every one of these objections might be admitted, however, and it would still remain apparent that the plate would be in a better condition both as regards crystallization and carburization if not heated above 2000° F. in cementation. In addition it is found that the edges and corners of plates are occasionally burnt, while unavoidable fluctuations of temperature sometimes cause hollows to be melted and scored into the highly carburized surface, which also shows large crystals.

2. Under the second head come the criticisms of the theory that pressure assists in retaining the carbon in the hardening form in quenching, and that therefore an arrangement of the surface by means of which the initial chill will immediately place an external layer of the metal of considerable thickness in a state of tension, and hence compression, thereby not only hastening and increasing its own tendency to harden, but bringing a more direct and powerful influence on the body of the plate.

Although Mr. Howe contends this theory in detail, it is quite satisfactory to note his final position. "While there is much to suggest that pressure increases the degree of hardening caused by any given quenching, I see no reason to believe that it plays an important part." Still it is well known that by forging through the critical point some carbon is retained in the hardening form. My object throughout has been to make use of every possible means of assisting the hardening; nothing should be considered trivial when it works in the right direction.

Mr. Howe's experience and distinguished reputation should, however, command the most careful attention to every objection he has made. For that reason I will go more at length into the various details than would otherwise be necessary. There is this great advantage in *expert* criticism, it is certain to help a good thing.

CEMENTATION.

With regard to page 20, last three lines. This paragraph as it stands is indeed incomprehensible. It should read "Powdered charcoal takes up O from the air, while the quick-lime absorbs moisture and slakes."

Page 21, line six and foot note. Mr. Howe makes the following statement: "The author, while correctly asserting that the phosphoric acid of bone-charcoal is not reduced in cementation, yet thinks that its phosphorus acts as a deoxidizing agent." A contradiction is here implied though none exists. In the text it is said, "the basic phosphate is not reduced;" in the foot note it is said: "It is the writer's opinion that P acts as a reducer of CO," there is no reference in the foot note to the basic phosphate of the bone-charcoal.

The use of CuO for Cu_2O is due to an omission unimportant so far as the idea conveyed is concerned; it is not a slip of the pen.

Page 8, line 6. A strong doubt has been expressed by certain metallurgists, who combine sound theoretical knowledge with much practical experience, as to whether the Harvey and similar processes actually improve inferior metal more than would be accomplished by careful annealing. The improvement in the gas check discs for example, is laid to the fact that the round bar from which they were cut contained *radial* forging strains which were released in the long annealing. Had the discs been *upset* before being machined and tempered, no trouble would have been encountered. It is asked, "Has the volatilization of any other component than that of sulphur been noted in the Harvey process?" In fact, no. Mr. Harvey's claim however is to carry on the treatment between the temperature of molten cast iron and that of about 3000° F. For some distance below the superior limit, various *reductions* will take place in the presence of the carbon gases. Chief among these is that of the oxide of iron found in overheated or burnt metal, rendering it brittle and of little value. It is well known that metal of this character can be made forgeable and capable of taking a temper when heated in contact with carbon. At the higher temperatures demanded in this process, the basic phosphate previously alluded to would also be reduced, and, as Mr. Harvey stated, would render the operation more rapid and effective, doubtless through assisting in reducing the oxide in the iron.

Page 21, line 17. With regard to cold iron absorbing carbon: In Landrin's Treatise on Steel, the following occurs: "Iron and carbon have a great tendency to unite even when cold. Iron left for some time in a mass of charcoal dust will become hardened, and by and by, may be transformed into steely iron." This work was translated by M. Fesquet, in 1868, so that it cannot be regarded as an authority on modern steel making; however, it would be absurd to suppose that M. Landrin, who was a practical man, did not know the difference between *iron* and *steely iron*.

Referring to the bottom of page 23, Mr. Howe says: "In Dr. Fleitmann's experiments, to which the author refers, it was reported that iron had the power of migrating in hot plastic nickel . . . It is in the highest degree improbable that either iron or carbon volatilizes as such in case-hardening or Harveying."

Dr. Fleitmann published the results of his experiments with various observations in *Stahl und Eisen*, vol. IX., pp. 9–12. I have been unable to gain access to the original memoir, but the following is from the Physical Property notes in the Journal of the Iron and Steel Institute, vol. I., 1889, p. 368:

"Some remarkable and regularly recurring phenomena . . . led the author to conclude that iron is volatile at a *medium red heat*, and experiments proved this to be the case . . . Further experiments showed that, although the iron is very volatile at this temperature, the nickel does not volatilize at all."

The dissimilarity of the words *Verflüchtigung*, volatilization, and *Wanderung*, migration, is so great that I am unwilling to accuse the staff of the Iron and Steel Institute of an error in translation.

The statement that a definite carbide is formed to which exception is taken might be qualified. Doubtless several carbides and multiples of carbides are formed, while much of the volatile or migrating material does not combine at all.

Page 27, lines 5 and 7. It is evident that the more porous the steel the more easily the gases of cementation penetrate it; the greater the volume of carbon depositing gas present, and the larger the surface of metal on which the carbon may be deposited or with which it may combine. It would seem, therefore, that the rate of cementation is a function of the porosity of the metal.

As to the connection between tensile strength and porosity, Dr. Thömer in *Stahl und Eisen*, vol. VI., pp. 166-168, gives the results of a number of interesting experiments stating: "As a general rule, it appears that the porosity is in inverse ratio to the tensile strength." He accounts for any exceptions to this rule, however, by the irregular disposition of the pores in an ingot, and the improbability of a single test piece representing the average tensile strength of the larger body of metal.

From this it would follow that steel of low tenacity, that is, porous steel, would carburize with greater ease than stronger steel.

The method of determination of the porosity of steel, in general terms, is as follows: Filings of the metal are placed in the receiver of an air-pump, which is then maintained in an exhausted condition for a considerable period of time. They are then brought into contact with a mobile fluid, such as 90 per cent. alcohol, capable of wetting the surfaces of the powdered metal. The diminution in volume of the liquid and the increase in weight of the filings give means for determining the volume of liquid absorbed; or the porosity. Dr. Thömer's observations on the subject were first published in *Stahl und Eisen* in 1884. Two years before, however, while attached to the Smithsonian Institution, I assisted the curator of metallurgy in determining the porosity of coke by a somewhat similar method.

Mr. Howe inquires, What is "porosity"? Dr. Thömer states that by "porosity" he understands only those pores which are of microscopic size, and not the larger blow holes or hollows.

Professor Tait's definition is as follows: "By the term pores we do not refer to *visible* channels, such as those which run in directions through a sponge, but to microscopic channels which pervade even the most seemingly homogeneous and continuous substances, such as solid lead, silver, gold, etc. . . The rapid passage of gases through unglazed pottery, iron and (hot) steel, etc., shows the porosity of these bodies in a very remarkable manner."*

Deville and Troost are said to have obtained very curious results with reference to the rapid passage of various gases through heated cast iron. Carbonic oxide was one of these gases (*Idem*).

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* Properties of Matter, p. 281.

Helmholtz and Root have proved that platinum is pervious to hydrogen even at ordinary temperature (*Idem*).

The ability of hot metals to absorb many times their own volume of gas in cooling is also an indication of their porosity. Methods of determining the quantities of these gases contained in the metal by drilling it under water might indicate their relative porosity.

Page 26, line 3 and page 37, line 1. "It is said that from this point (1200° F.) the metal becomes more and more dense until fluid"; page 37, line 1, is undoubtedly erroneous except it be taken in the most general sense. I am fully aware, as Mr. Howe explains in his Metallurgy that neither contraction nor expansion in cooling and heating are continuous and regular. What I should have said is that from this point, 1200° F. the metal expands rapidly but neither regularly nor continuously to a temperature in the vicinity of 1832°, after which, at some higher temperature, it contracts, becoming when fluid even more dense than it was at 1200° F. This matter is, however, correctly treated on page 25.

The fluid density of steel given in the paper was obtained from the Physical Property Notes in the Journal of the Iron and Steel Institute for 1881. Mr. Howe's statement that "the enormous shrinkage which occurs in the *early* part of the cooling of steel castings" refutes my assertions as to the density of fluid steel is hardly correct. Neither is it a wise one for his argument. The thinnest sections of the casting undoubtedly solidify first, and the skin of solid metal covering them at any time in cooling is stronger than that covering the thicker parts, as the cooling of the latter is retarded by the larger volume of plastic or fluid metal. The external shrinkage of the latter in solidifying over this expanded mass is small, hence the cause of shrinkage cavities in these enlarged parts. It would appear, if Mr. Howe is correct, that if the founder waited before releasing the casting until the heavier parts were sufficiently firm to support themselves, that the thin and stronger parts, in which the maximum linear and superficial contraction takes place would already have fully contracted and torn themselves apart over the core. On the other hand, it is found possible, provided the design is not such as to brace the casting against its own contraction, to make sound and yet quite complicated castings.

The successful development of steel casting as applied to complicated designs of gun carriages and engine frames may be said to have begun in this country in 1887. About this time I was fortunate enough to gain considerable experience while attached to the Washington Gun Factory as Assistant Inspector of Ordnance in charge of the construction of 6 and 8-inch gun carriages.

This is the practice at present: an allowance for shrinkage, graded according to the section and location of the part, is made in the pattern, which is therefore considerably larger than the casting required. At the earliest possible moment *after the metallic surface has solidified* in the mould water is turned into the hollow core which is thus weakened or dissolved while the mould is loosened up and stripped, to permit the casting to freely contract. Now, the experiments of Mr. Howard at the Watertown Arsenal* have shown that at a temperature of about 1600° F., metal very similar to that of which steel castings are made has but 14 per cent. of its tensile strength when cold; the elongation is also much less on account of the weakness of the metal; there is also every reason to believe that the metal becomes rapidly weaker as it approaches the melting point. Now, if the metal is weaker, as we know, and contracts more, as Mr. Howe states, in the early part of the cooling, it must be apparent to all that the casting would tear itself apart before it would be possible to remove the core and mould which oppose its contraction. The fact is that were it not that the density of the casting when its skin is first solidified is less *if it differs at all* from that of the fluid metal, it would be impossible to make cored castings. The metal in the first setting would be unable to contract over the core without tearing apart and it would be impossible to strip off the mould until it had set. If the major contraction occurred in the change from the *fluid* to the *plastic* state, shrinkage cavities in large ingots would not be tear-shaped, as the viscous metal would close the points up. In support of my opinion that the major part of the contraction occurs in the change from a plastic to a rigid condition and hence comparatively *late* rather than *early* in the cooling, I quote the following from an experiment made in cast iron by Mr. Thomas Wrightson.† Strange to say, Mr. Howe refers to this same experiment to prove that the enormous shrinkage occurs "in the early part of the cooling." I see in this experiment nothing but a confirmation of my expressed opinion that the major part of the contraction occurs *in cooling from a temperature of* 1832° *F.*

Four-inch cast iron balls were suspended upon a spring and submerged in a bath of liquid cast iron. By attaching a recording apparatus to the spring it was possible to form a curve which showed the change in volume of the balls as they heated. On the diagram the vertical ordinates show the positive and negative buoyancy of the ball due to its varying expansion, while the abscissas represent the times of submersion. The sharp oscillation x occurred in loading the spring. It will be seen that the cold iron had a negative buoyancy of 2 oz; in 23 seconds it had expanded until it had the same density as the fluid metal; in 2.5 minutes its expansion had produced an upward pressure or buoyancy of 10 oz.; in 4 minutes its buoyancy was at a maximum, 11 oz. At this point it was found that the ball was in a plastic state, as fine wires could be passed through it. At E the ball apparently began to dissolve, an action which had, it is supposed, commenced at D. Sir Lowthian Bell states with regard to similar trials that he had made with cubes of iron, "they sank to the bottom and remained there about 30 to 40 seconds, and then rose to the top, where they remained." Mr. Wrightson further states, "no doubt,

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* On the Physical Properties of Iron and Steel at High Temperatures.

† Journal of the Iron and Steel Institute, 1879, 1880 and Vol. I., 1891.

from what had been observed as to the floating of steel in a bath of steel, the diagram of a steel ball would have similar, though probably not identical, characteristics." As a result of this experiment it was found that the specific gravity of fluid cast iron was 6.84 while that of the plastic metal was 6.32, a difference of 8.2 per cent. I am unwilling to go as far as Mr. Alfred E. Watkins, who states: "It is useful to know that all shrinkage takes place while the casting is changing from a red to a black heat."* But it would appear that I have just grounds for believing that the maximum contraction occurs much later than Mr. Howe appears to intimate.

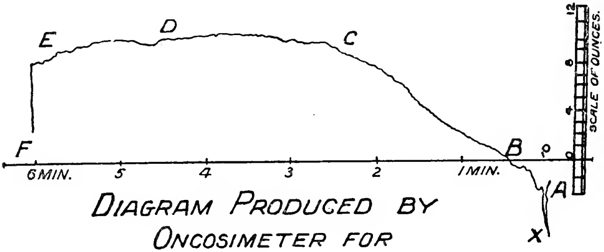

DIAGRAM PRODUCED BY ONCOSIMETER FOR CAST IRON.

Page 24 and 25. Although but a matter of conjecture, I prefer my own formulas of cementation to those presented by Mr. Howe.

In the first place, his formula $2CO = C + CO_2$ is hardly complete, and there seems doubt as to its accuracy at high temperatures. The combination here indicated is dependent upon the presence of a peculiarly receptive, perhaps *nascent* is the word, surface as in the case of iron sponge, or upon some other material as oxide of iron, which will serve as an intermediary, as shown in my formula in the reaction. This matter is touched upon in the first paragraph of page 24. Mr. Howe's formula is also far less simple than it looks. It is well known that CO passed over heated oxide of iron, or spongy iron, is split up into CO_2 and deposited carbon. In the case of the spongy iron, however, some of the iron is always oxydized, indicating that the reaction is more complicated than appears from this formula. Also at a bright red heat the deposition of C is *practically suppressed*; in fact, Sir Lowthian Bell† states that at a bright red heat it would appear that the oxygen absorbed by the iron reacts on the deposited carbon. Speaking, on page 187, of the splitting up of CO in this manner, he states: "In the description of this curious rearrangement of the elements I suppose that the reducing agent must be a

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* N. S. Spretson, A Practical Treatise on Casting and Founding, page 158.

† I. Lowthian Bell, Principles of the Manufacture of Iron and Steel, page 187.

lower oxide of iron, and that the action was probably of the nature expressed in the formula

$$\mathrm{Fe_xO_y + zCO = zC + Fe_xO_{y+z}}.\text{"}$$

It would hardly seem, therefore, that the phenomenon of cementation was "more clearly explained" by the first at least of Mr. Howe's formulas, since that formula of itself requires expansion and modification in explanation until it strongly resembles one of those it is intended to supplant. It is simple only in this respect, that it does not pretend to tell anything.

The objections to the second formula $CO_2 + C = 2CO$, representing an actual reaction, are based upon the conditions under which it must take place. It is a question as to the manner in which the cementation gases penetrate the heated metal, the pores of which in its cold state contained a condensed mixture of gases many times its own volume. A large part of these are of course expelled in bringing the metal up to the temperature of cementation, so that it would then appear that the entrance of the carbon gases is probably of a selective character, possibly through chemical reaction. It seems, however, more probable that they enter through diffusion or the establishment of convection currents. If the gases are forced in through the pores by pressure from the exterior, whether through heat expansion or as in Schneider's gas process, the action is one which Graham has called *transpiration*. He found that a volume of CO_2 passed through capillary tubes under pressure in 83 per cent. of the time required by an equal volume of CO.[*] One would be inclined to believe therefore that, after the reaction indicated by Mr. Howe's first formula, the resultant CO_2 which is, of course, formed with the evolution of considerable heat, would pass on into the metal, instead of returning to the surface to pick up additional carbon. Especially is this the case as the entering CO_2 is warmer and more expanded than the gas existing in the pores which it displaces. From this it would seem not altogether improbable that the oxygen in the carburizing mixture is gradually exhausted.

Page 29, sixth line from bottom. The criticism of the statement that the *height* and *duration* of the *hardening temperature* affects the amount of carbon dissociated is just.

"Change of carbon from the 'hardening' to the 'cement' form requires not only a correct temperature, but a certain amount of time, while on the contrary, the change from the 'cement' to the 'hardening' form depends only upon the temperature and quenching seems consequently to prevent any change from 'hardening' to 'cement carbon.'"[†]

This also covers the criticisms of the statement made on page 30, line 3, that the toughness of the metal after quenching increases with the length of time of exposure to the higher temperature, and that near the bottom of page 29, that the hardening tendency is proportional to the duration of the

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[*] Chemical and Physical Researches, 1876.

[†] J. A. Brinnell, Stahl und Eisen, November, 1885.

temperature of hardening. The errors arose from a confusion of heating for *hardening* with heating for *tempering*.

In Howe's Metallurgy, page 23, is found "Heating for tempering . . . the hardened steel must be reheated uniformly. If slowly heated the steel is said to become tougher than if rapidly heated, without corresponding loss of strength and hardness."

Page 29, third paragraph. It is true that the stress of hardened bodies may be inferred from other evidence than their decreased density. The well known experiments of J. H. Howard,* at the Watertown Arsenal, indicate clearly, however, that although a part of the increased volume *may* be due to a chemical change, still it *is* largely due to the exterior having become fixed in cooling over an expanded interior.

Professor Langley's experiment is said to have merely made the metal slightly lighter and that no measure of hardness was attempted. Mr. Howe appears with great nimbleness now on one side of this argument and then on the other. In the preceding paragraph he takes exception to a change of density indicating stress, as it may be explained by a change of chemical constitution ; he now denies the chemical change, though admitting a change in density. Hardness and elasticity are intimately associated, so that, whether the difficult task of measuring so slight a change in hardness was attempted or not, the steel in Professor Langley's experiment, being less dense, was in a state of stress and its surface actually, though probably very slightly hardened.

The statement that the unsatisfied affinities of the carbon for the iron probably places the whole body in a state of constraint is evidently incomplete. Chemical affinity is potential energy, it cannot exert stress without being transformed in the act of combination. In the following paragraph the matter is made clear, however, when it is stated that certatn of these chemical affinities are appeased in time, as in the case of tools, or even through slight fluctuations of temperature, as in Professor Langley's experiment in hardening steel by quenching from a temperature of boiling water.

Mr. Howe's statement, "Speaking broadly, the density of steel is inversely as its tenacity," is a most remarkable one. No wonder that he does not dare make use of it to infer "*that the porosity . . . should be directly as the tenacity*." If that was true, then ingot metal would be stronger than forged steel. Such a statement, however, naturally follows the taking of a very narrow, rather than a broad, view of the idea criticized. Mr. Howe doubtless refers to the fact that untreated steel has less tenacity than when tempered or hardened ; also, that the density of untreated steel is greater than that of hardened steel, and perhaps that high carbon steels which are stronger than mild steels are also less dense. But here he falls into an error which has prevented him from grasping my meaning, and

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* "On the Initial Strains in Some Tempered and Annealed Steel Cylinders."—Notes on Construction of Ordnance, No. 41.

led to baseless criticisms in a number of instances. He makes no distinction whatever between the density of a *body* and that of the layers of which it is composed. His views appear to be gathered from the behavior of test specimens, mine from specimens forming a part of an armor plate. These layers, especially in a face hardened armor plate vary in density from surface to center, and this fact cannot be omitted from consideration in the discussion of the porosity of steel. The lighter density of hardened steel is easily explained. Barus and Strouhal state that, "in the case of steel (cylindrical rods) hardened by tempering, we observe a dense external shell surrounding an abnormally rare core in such a way that greatest intensity of stress is exerted in the radial direction; *i. e.*, at right angles to the axis of figure."* In fact the less density of hardened steel is due almost, if not entirely to the enlarged figure arising from the exterior of the body becoming fixed in cooling over the heated and expanded interior.

The result is that the exterior, contrary to the accepted idea, is *always in compression*; first, a *radial* and then, as the central body contracts, a circumferential compression. This, without any aid from chemical change would go far towards making the exterior more dense than the core.

The failure to recognize this fact may explain Mr. Howe's opinion that water quenching has little effect on the modulus of the surface of Harveyed armor plates.

In passing, however, I desire to call attention to his comment in comparing line 26, page 32, with lines 1 to 4, page 33. It is, "He asserts that water-quenching highly carburized metal *greatly increases* the modulus of elasticity. Such evidence as I have met agrees with his previous and opposing assertion (page 32, line 26), that *water-quenching* has little effect on the modulus."

The statement on page 32 referred to is: "It is known there is no difference whatever, under the elastic limit, between the extension, for equal stress in equal lengths, of soft and *tempered* steel." Mr. Howe has no right to say that *tempered* steel is *water-quenched*. Perhaps, however, this is an instance of heterophasia, for on page 17 of his Metallurgy I find —"DEFINITIONS.—1. STEEL IS HARDENED (in the specific sense of the word) by sudden cooling from a high temperature, usually at or above redness, *e. g.*, by plunging it in water, oil, etc.

"2. *To temper* (to qualify, to soften) in its specific sense means to mitigate, to partly remove, to moderate the effects of previous hardening. . . . I shall use the word exclusively in this sense, though it is often and not incorrectly employed generically to designate any sudden cooling, whether from an excessively high or a moderate temperature."

The statements in the essay do not require clarifying. On the one hand, steel, say of .35 per cent. carbon, is moderately hardened by dipping in oil, the density of successive layers from surface to heart are practically uniform, not greatly diminished, and the modulus is not perceptibly changed.

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* "On the Physical Characteristics of the Iron Carburets."—Bulletin, No. 14, U. S. Geological Survey.

In the other case, steel originally containing but .22 per cent. of carbon, has been cemented so that the carbon in the exterior layers is brought up to perhaps over 1 per cent. The plate is then chilled in the most rapid and violent manner possible by a spray of ice cold water containing salt. The interior of the plate is toughened, but its modulus is no more affected than in the case of oil tempering. It is different with the thin highly carburized exterior, the density of which is made greater than that of the interior by the intense compression over the latter when expanded, resulting from the treatment, a compression which exists from the beginning to the end of the quenching.

Now, to connect the density with the modulus. Dr. M. G. Wertheim* in discussing the constancy or the variability of the coefficient of elasticity in the same substance under different circumstances, and the changes that mechanical treatment, annealing, and elevation of temperature can produce in it, states:

"In each condition the density of the metal was noted; then I determined its coefficient of elasticity and the rapidity of sound, by means of three different methods: by transverse vibrations, by longitudinal vibrations and by elongation. These then are the conclusions that may be drawn from these experiments:

1. The coefficient of elasticity is not constant for the same metal; whatever augments the density increases it, and reciprocally. . ."

M. Poisson has also been led to the following expression for the coefficient of elasticity:

$$q = \frac{\pi}{g} \int_{r=x}^{r=\infty} \frac{r^5}{a^5} \cdot \frac{d \frac{1}{r} fr}{dr},$$

in which a is the mean distance of the molecules, r the radius of action of the molecule, the function fr giving the result of simultaneous action of the attractive molecular force, and of the repulsion due to heat. The product qa^7 was found nearly constant for the same metal which would make the modulus vary with the seven-thirds power of the density.

The experiments of Dr. Wertheim, which were of exquisite delicacy, were also carried on with alloys, in the case of which the same conclusion was reached.

Now, on the other hand, the numerous experiments of Mr. Howard and others at the Watertown Arsenal, in fact the results of almost every experimenter, seem to indicate that hardening *does not* increase the modulus. This is contrary to the conclusion to which I have been led, for the apparent contradiction may be explained by the change of modulus in the successive layers of different density in the hardened specimen. Thus the modulus of the rarefied interior would be less than in the case of the untreated specimen, while that of the dense external layer would be greater, the result being that, so far as the whole body was concerned, no

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* Comptes Rendus, vol. 15, 1842. "Researches on the Elasticity and Tenacity of the Alloys."

appreciable change in the modulus occurs. In fact this would seem to agree with Dr. Wertheim's experiments on the modulus of alloys, his conclusion being, "The coefficient of elasticity of the alloys agrees sufficiently well with the mean of the coefficient of elasticity of the constituent metals, some alloys of zinc and copper being the only exceptions.[*]

It thus appears that both Mr. Howard's and Dr. Wertheim's conclusions *may* be correct, and if they *are*, the modulus of the external layers of metal, the only ones which have been hardened to any extent, *must* have been increased, perhaps not greatly, as stated in the essay, but certainly to a considerable extent.

But we may get at this in another manner. Attention is called to the intimate relation borne to the *resistance to compression*, and the *rigidity* by the modulus of elasticity, and the considerable effect which must be produced on these coefficients by the rapid quenching accompanied by great pressure contemplated in the proposed armor plate. This modulus is expressed in terms of the compression coefficient K, and that of rigidity n, by the expression $\frac{9Kn}{3K+n}$.[†] Now Mr. Howe admits that the compressive strength of the hardened layer on the armor plate is greatly increased by quenching, and we know that its rigidity is also vastly greater than it was before hardening; hence, unless the expression here given is incorrect, the modulus must have been considerably increased.

Page 39, lines 10 and 11. The statement is made with regard to manganese steel, "the author falls into the curious error of supposing that manganese steel forges particularly well, and 'welds with facility.'"

I am perfectly aware of the intractable nature of steel containing a high percentage of manganese. I am informed, however, that steel containing from 12 to 14 per cent. of manganese may be easily forged if brought up to heat *very* slowly, and that a temperature of 1900° F. be not exceeded.

My authority for the statement regarded as erroneous is the following paragraph from a paper of M. Brustlein, of the Holtzer Steel Works, France, which was read before the Iron and Steel Institute in October, 1886: "Manganese steel works better hot under the hammer than chrome steel, but manganese steel works particularly well. Again, manganese steel welds with great facility, while chrome steel welds badly or not at all."

I also refer to Howe's Metallurgy of Steel, page 42, "So, too, the presence of manganese in solidified steel appears to hinder its oxygenation in heating and forging." Also on page 44 of the same work I find: "As sulphurous irons are malleable at a high, but brittle at a low (red) heat, while phosphoric irons are malleable at a red, but brittle at a high heat, and as manganese counteracts the effects of both, and as it moreover counteracts hot shortness, no matter at what temperature, and from what cause it

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[*] Comptes Rendus, vol. 16, 1845, pp. 978–1000.

[†] Properties of Matter, P. G. Tait.

may arise, whether from phosphorus, sulphur, copper, silicon, iron oxide, suspended silicate of iron or blowholes, we may ascribe its effects to its directly increasing the plasticity of the steel at all temperatures at and above redness, to its even increasing the range of temperature through which plasticity prevails, on the one hand raising the melting-point, on the other lowering the point at which plasticity gives way to rigidity."

Hadfield asserts that the most manganese that can appear in low manganese steel without rendering it wholly brittle and rotten is 2½ per cent. I certainly had no idea of approximating to that amount.

It must be apparent to all that neither M. Brustlein in making the original statement concerning manganese steel, nor I in quoting from his remarks, referred to the high per cent. manganese steel which, in fact, is claimed by Mushet, and admitted by Hadfield to be an iron *alloy* rather than a *steel.*

Page 34, seventh line from the bottom. Exception is taken to the statement "Both the tensile strength and ductility of the mildest steels are greatly increased by quenching." A similar statement, however, is found in the first report of the committee to the Council of the Institution of Mechanical Engineers, 1883, thus : "There are abundant illustrations of his (Chernoff's) theory to be found in the many writers on steel who have been consulted. Thus Hackney states that quenching mild steel improves its tenacity and ductility." Quenching refers in this case to quenching from *above* the critical point. Possibly the statement should be qualified, if used generally, as my experience has been of a special rather than a general character.

A few typical cases of improvement by quenching are submitted from a large number at hand. The tests are all longitudinal and taken from the middle thickness of face hardened armor plates ; those marked B are from the lower end of the plate referred to the ingot, while those marked M are from the upper end. The most marked improvement, as a rule, occurs in the former. It may be said that metal at the heart of the plate cannot be quenched, still the improvement is almost invariable in plates under six inches in thickness, becoming less and less frequent as the thickness increases, until in plates over twelve inches thick it is so rare as to lead to the belief that it is in these cases probably due to a variation in the quality of the metal. This fact of course disposes of Mr. Howe's remark that it is improbable that the more sudden and complete the chill, the greater the increase of toughness in the body and back of the plate, as I state on page 35, line 1, for it is evident that the bodies of the thick plates are less affected by the chill than those of the thin ones. It must be again apparent that the results obtained from the treatment of small test specimens give only a general guide as to the behavior of large masses when similarly treated.

In further support of the stated improvement produced by quenching, attention is called to the fact that the French armor makers of the Loire district no longer employ oil tempering on armor as they get better results from water quenching.

TABLE SHOWING THE IMPROVEMENT PRODUCED IN ARMOR PLATES BY QUENCHING.

Plate Number.	Thickness.	Mark on Specimen.	Before Quenching.		After Quenching.	
			Tensile Strength.	Elongation.	Tensile Strength.	Elongation.
B-21	3″	BI	81,500	17.5	103,400	22
A-951	3″	BI	73,100	25	82,900	30
		MI	78,210	23	91,000	28
A-953	3″	BI	71,320	26	102,420	30
		MI	83,680	20	108,900	26.5
A-962	3″	BI	65,440	25.5	80,080	29
		MI	81,000	20	85,990	26.5
A-963	3″	BI	65,450	25	70,840	35
		MI	81,000	20	81,800	31
A-937	3″	BI	79,460	24	96,800	28
A-928	3″	BI	75,900	22	91,510	28
A-970	3″	BI	65,970	25	81,370	31.5
B-42	3″	BI	81,620	23.5	103,780	27
		MI	88,780	12	114,600	13
A-865	3.5″	BI	75,400	27	81,540	27.5
B-46	3.5″	BI	75,660	26	89,840	32.5
		MI	77,170	23.5	91,630	26.5
A-775	3.5″	MI	77,440	15	79,830	27.5
A-773	3.5″	MI	74,880	23	88,960	26.5
B-136	4″	BI	78,730	21	102,150	24
B-17	4″	BI	76,160	23.5	88,450	27.5
		MI	77,430	22.5	92,400	26.5
A-973	4″	BI	75,900	22.5	87,260	35
		MI	79,240	22	94,200	27.5

TABLE SHOWING THE IMPROVEMENT PRODUCED IN ARMOR PLATES BY QUENCHING—*Continued.*

Plate Number.	Thickness.	Mark on Specimen.	Before Quenching.		After Quenching.	
			Tensile Strength.	Elongation.	Tensile Strength.	Elongation.
B-16	4″	BI	75,140	22.5	102,070	27
		MI	77,940	16	107,360	20
A-988	4″	BI	71,320	26	90,340	31
		MI	76,700	13.5	96,250	23.5
B-120	4″	BI	74,690	25.5	92,530	30
B-124	4″	BI	72,640	25	91,000	32
		MI	80,340	24	102,200	26
B-112	4″	BI	83,160	22	101,230	30
		MI	87,370	20.5	113,960	22.5
B-220	6″	BI	78,030	22	98,300	22.5
B-206	6″	MI	75,260	20	77,000	28
B-229	6″	BI	83,250	20.5	91,380	21
B-226	6″	BI	85,840	21.5	92,020	22.5
B 227	6″	BI	87,680	20.5	106,770	23
B 196	6″	BI	74,430	23	94,070	24
B-191	6″	BI	69,080	23	77,770	26.5
A-816	8″	MI	81,000	13	100,970	14
A-747	8″	BI	72,600	18	75,150	29
A-806	8″	BI	85.730	20	86,100	25
A-874	8″	BI	77,940	25	85,850	24.5
		MI	87,620	19	93,560	22.5

The charge that I confound ductility with toughness seems hardly just. The body and back of the plate are already ductile as it comes from the rolls; longitudinal specimens are made even more ductile by the removal of the longitudinal forging strains in heating. There is excellent authority in Mr. Hadfield and Dr. Ball for believing that the increase of tensile strength is probably due to the strains (transverse) produced in the metal by quenching.*

Mr. Howe states with regard to this charge of confusing toughness with ductility: "To the same apparent error I ascribe his mistake . . . that, save at the very surface, the plate is decrementally *toughened*, not decrementally *hardened*. Here he appears to be completely in error."

It is difficult to conceive how the language used in the essay can be forced to convey any such meaning. The statement is very clear, and is: "So far as hardness pure and simple *is an advantage* to such armor it is usually confined to a comparatively thin and uniform layer, below which the metal exists in a decrementally toughened rather than hardened state."

A great range of hardness is certainly passed between the surface and heart of the plate. But below the surface layer the valuable characteristic is the toughness which gradually diminishes towards the back of the plate. The decremental hardness is in fact a disadvantage just as soon as it requires less work to crack and displace the metal than it would to cause it to yield by deformation if slightly softer.

THE PROPOSED ARMOR PLATE.

Mr. Howe has omitted the following from my contentions as to the effect of gashing the face of the plate:

1. It will limit cracks.

2. By increasing the degree of hardening for a given temperature on the corrugated or gashed surface, it will permit the use of a stronger foundation plate without rendering it brittle through excessive hardening.

3. That the various gashes or depressions constitute hooks and ridges of hardened metal possessing great transverse strength, and which through their depth produce the effect of an interlocked arrangement of girders.

4. That the penetration of the carbon may be controlled, being extended or limited according to the thickness and original composition of the plate, and that practically the same percentage of carbon may be carried into any desired depth.

5. That no unnecessary carbon is introduced, in order to secure a chilled surface of the desired thickness, by means of which excess of carbon the toughness of a considerable part of the plate is sacrificed through its being made brittle hard.

6. The chill or maximum hardness may be carried to any desired depth.

7. The bodies of thick plates are made more accessible to heat treatment, and that without increasing their carbon percentage.

As many of Mr. Howe's objections would, in all probability, never have

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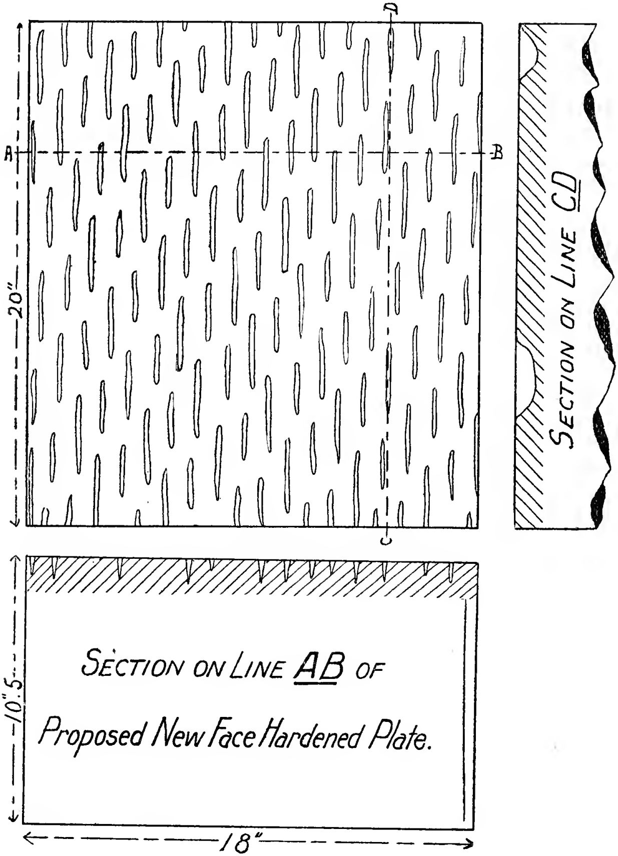
*Journal of the Iron and Steel Institute, 1891. "Changes in Iron Produced by Thermal Treatment."

been made if he had more clearly understood the arrangement and dimensions of these gashes a few explanatory sketches are added.



With regard to Mr. Howe's remarkable statement that by ridging the plate the "saving of time and fuel, while it might exist, would be inconsiderable;—so slight as to be wholly unimportant."

If the ridge part, as Mr. Howe admits, would absorb heat more quickly, it would commence taking carbon more quickly, which is the end in view, rather than that of heating the body of the plate. Any one who has ever built a fire and appreciates the use of kindling wood, or a crumpled newspaper rather than a tightly folded one, or still nearer to the point, projecting ridges or splinters from heavy wood, will recognize the fact that the ridges of metal, although possessing greater conductivity than the wood or paper, will attain the desired temperature far more quickly than the body of the plate. Now the surface immission, the *conducibility* per unit of area of surface as Fourier calls it, is the same over the greater part of the ridges as it is in the case of the flat plate. Doubtless it is somewhat less at the bottom of the gashes. We have, however, in one case, heat flowing into the top and sides of a ridge, while it can only flow out at the bottom. In the other case, heat flows in through a surface equal in area to the summation of the areas of the bottoms of all the ridges; that is, the flat surface of the plate.

As the entrance of heat per unit of surface in each instance is equal, being dependent on the temperature of the source and the conducibility of the metal, a peculiar condition exists in the case of a projecting ridge of square section: *it is receiving three times as much heat* as would be the case if it was flush with the surface in a smooth-faced plate. Now, the rate of flow per unit of area from the ridge across its base into the body of the plate is proportional to the difference of temperatures. But that rate cannot be greater at the start than the rate of flow per unit of area into the ridge, for if it were, the base receiving more heat per unit of time than an equal area of surface would become hotter, and a flow would be established from the base towards the surface. *It therefore becomes apparent that no more heat can pass out of the ridge through its base than is received through an equal area of its surface*, in fact not as much; *in other words the ridge must be getting hotter at a rapidly increasing rate.* There are certain other conditions which emphasize this effect. The hotter the ridge becomes the poorer its conductivity; there is less heat transmitted to the body of the plate for the same difference of temperatures. This decrease of conduction is enhanced by the increase of the hot metal's specific heat, it requires considerably more heat now to raise its temperature one degree; besides the rate of admission falls as it rises in temperature. It should be noted that Mr. Howe seems to have regarded the conduction as proportional to the *amount* of heat absorbed by the ridge rather than the difference of temperature and the rate due to the time. In no other way can we explain his statement, "that the heating of the body part might be hastened because the greater surface of the ridges would absorb heat more quickly, and because the high conductivity of the metal would quickly transfer into the plate any heat taken up by the ridges." This problem is far more complex than appears from my incomplete statement.

The temperature of the surface increases at a decreasing rate; that of the base increases at an increasing rate; ultimately the base will approximate the surface temperature; even then, however, no more heat can pass through it than enters an equal area of the surface, or it would become hotter than the source from which its heat is obtained.

Now, no part of a ridge can become hotter than its surface, for if it were, there would be a flow of heat towards the surface. It therefore follows that a point in the ridge will become hotter than one at an equal depth in a smooth plate in equal times, so that the rate of transmission of heat from that point into the body ot the plate will be greater, and this rate will increase as the ridges become more and more hot than the body. It does not follow from this, however, as Mr. Howe states: "The high thermal conductivity of the metal which would transfer into the plate with extreme rapidity the increased quantity of heat which its increased surface led it to absorb." This assertion is plainly an impossibility, and could only have arisen from a failure to comprehend the fundamental law of the transmission of heat; that is, that the rate is a function of the *time, distance, and difference of temperatures.*

This conclusion is independent of the rate at which heat reaches the plate, it is just as true of the direct blast of the furnace as it is of heat slowly filtering through an asbestos protection or carried by convection currents in the atmosphere.

I will regard it as demonstrated that carburization will begin *much* earlier in the ridged than in the smooth plate.

Mr. Howe is correct in his belief that the *excess* of carbon taken up by a gashed plate would be found in the ridges alone. That is where it is wanted. One of the principal defects of the present process is that in order to get a fair percentage of carbon on the surface, it is necessary to run the carbon in deeper than desired, deeper than will be affected by the true chill, and even if it were all retained in the hardening condition by quenching, toughness would have been sacrificed over a considerable thickness of the plate; the result obtained being something more nearly akin to a weldless *compound* than the theoretical *face hardened* plate described in the first paragraph on page 64. I am aware that certain foreign armor makers have boasted of being able to Harvey a 10-inch plate to a depth of 2.5 inches. If they did, the plate as a whole was brittle and less resisting than it would have been if Harveyed to a depth of 1.25 inches; they merely lost the toughness that should be found, in metal with an elastic limit well below its failing point, over a thickness of 1.25 inches.

This matter is not discussed at great length in the essay, but it is in fact one of the most important reasons in favor of the adoption of the process advocated. A reference to Lieutenant Stone's remarks and diagram illustrating this subject is ot advantage at this point. Without doubt the metal is much strengthened to the inner line of carbon penetration; but its elastic limit is near its failing point; but little work can be done upon it; *it cannot absorb much of the projectile's energy.* It lacks therefore the prime qualification of toughness. It is proposed by isolated gashes to carry this hardness with its great compressive and transverse strength into at least an equal depth over lines forming a net-work of girders, and yet separating and partially underlying them will be a matrix of metal untouched by the carbon, and retaining all of its proper toughness. This arrangement will permit an enormous amount of work to be done on the face under impact, without destroying the plate.

Mr. Howe compares the gashed surface with a crimped strap. As the sides and edges of the gashes are the first to chill and set, they are quite different from extensible crimps; in fact they may be regarded as local increases in thickness and rigidity; further on, however, he states: "We may admit that corrugations might increase the transverse strength." If the skin is in tension over the body, it compresses it, *and is compressed in turn*, action and reaction being equal and opposite; this of course assists the action of the cooling medium. Again, the ridges having a much greater area of emission than the part of the body they cover, will cool more rapidly. Not only that, but the rate of emission is dependent upon the size of the body,* and may be represented by a constant plus a term inversely proportional to the radius, for example, of a cylinder The heat being emitted more rapidly from unit area of the ridges, therefore, than from unit area of the flat surface, the instant the spray strikes the plate, each gash is boxed in by hardened steel of great strength—very different from a crimped strap—so that the combined cooling and compressing effect is felt on the body of the plate much earlier and more powerfully than when it is flat and smooth.

Let us regard the effect of gashing on the loss of heat by the *body* of the plate in quenching. Heat flows directly from the bottom of the gashes which are, according to their depth, that much nearer the heart of the plate. Also, by the far more rapid chilling of the ridges than an equal depth of metal in the case of the flat plate, the temperature of the plane separating the ridge part from the body of the plate will at any time t after the commencement of spraying be considerably lower in the case of the ridged than in the case of the flat plate. Heat will therefore be more rapidly extracted from the body in the former case than in the latter. This will make the hearts of thick plates more susceptible to heat treatment, and something of the improvement noted in the case of thin plates may be expected.

It will thus be noted that Mr. Howe's contention that the *interposition of the ridges between the body and the water* greatly lessens the tensile, compressive and transverse strength of the body part is incorrect. It is

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* Transactions of the Physical Society, Jan'y 11, 1895. Mr. Eumorfopoulos, The "Determination of Thermal Conductivity and Emissivity."

also apparent that thick plates can be affected by quenching to a greater depth; or, if desired, the same results may be obtained by quenching at a lower temperature, thus decreasing distortion.

I am not aware that I have confined my attention too much to hardness proper, the object of the hard face and the necessity of transverse strength is noted at the top of page 56. Emphasis was laid upon the remarkable compressive strength of the chilled surface in discussing the modulus on page 33. But it is endeavored to limit the hardness with its accompanying brittleness to just that which is necessary to prevent a forward movement of any portion of the surface to accommodate the metal displaced by the penetrating projectile. More hardness or rigidity than that is not wanted, there is no use for it; the metal becomes brittle; a crack started in the surface will run through it, for its elastic limit is close up to its failing point, so that despite its high tensile strength, it can absorb but little work. It is not wished to obtain a metal with less tensile strength, but one with some elongation, and this is possible, for it is known that the tenacity of the metal is not directly connected with either its hardness or brittleness. This may be said to be the text on which this essay was written. It seems odd that Mr. Howe should think I lay too great stress on hardness, when I believe myself to be the pioneer in advocating its limitation and control in face hardened armor.

Mr. Howe's resolution of the *resistance* of a plate to penetration is open to objection, especially with regard to the "radial resistance which the face offers to being driven parallel with itself, radially away from the point of impact, as the ogive progressively forces its way farther and farther into the plate." It is not the amount of *resistance* that the plate can offer which tends to shear off its surface or widen the impact, but the *force* that can be exerted by the projectile. *Resistance* may be regarded as inversely as the *deformation* or work done upon the plate; in hard, brittle plates, however, this is not the case, as comparatively little energy is expended in breaking them up. Mr. Howe recognizes this fact in ascribing a lack of *tenacity* under impact to quartz and chilled iron. Now, it must be apparent to every one who will press the point of a pencil into a rubber pad that *until penetration is effected* the surface is brought into *tension* by the force exerted, and the resistance of the body of the pad tends to prevent the flow of the surface *towards* the pencil point instead of *away* from it. When some penetration is effected the tension on the surface is no longer direct, being then due to its connection with a lower layer still before the point. The penetrated surface may then be placed in compression immediately around the point and then, in the case of rubber or soft metal, it will be curled up into a fringe. It is different in the case of a face hardened plate; its elastic compression and extension is greater than in the case of softer steel, but it cannot get out of the way by flowing and curling up into a fringe. In consequence it resists obstinately and directly to the force acting upon it instead of evading it by flowing radially. Now, the force acting upon the cone of depression is, as has been stated above, one of tension, generally, and *compression* directly where the face of the ogive is in contact with it. It must therefore be seen that as the ogive penetrates the plate and comes into contact with successive zones of the cone of depression, a compressive force is brought upon these zones acting in a line normal to the ogive at the point of contact. The hard face is therefore *crushed into the body* and carried forward, enveloping the head of the projectile. A radial shearing component parallel to the face undoubtedly exists, but it is comparatively unimportant until the ogive is well entered, and the hard face has practically completed its *direct* work of resistance. At this later period of penetration, the resistance to the shearing of the hard face is increased, not diminished by the gashes, for these form hooks penetrating the tough body, and by their similarity to a net work of girders bound in a tough matrix can neither be sheared nor crumpled up. Lieutenant Chambers in the discussion shows considerable appreciation of this feature. There are, however, in existence claims to the right to use this method as a means of introducing and regulating the percentage not only of carbon, but of chromium and other elements in the various processes of cementation.

Mr. Howe admits that the corrugations would possess greater transverse and compressive strength than the flat plates, yet states "that a 10-inch plate with half-inch gashes would be much weaker than a 9.5 inch ungashed plate." His error lies in failing to see that the plate resists *as a whole*; the resistance of the hard face and that of the tough body and back cannot be separately considered; they are inextricably involved with each other.

As to the cost, the required depressions, ridges, or corrugations, may be put in the plate by a single passage through the rolls. They must be introduced in tapered plates under the press or hammer; in either case the last forging heat may be utilized for the purpose. The Carnegie Steel Company has recently shown that by carburizing a plate 17 inches thick, then forging it down to 14 inches and quenching, its resistance was greatly increased. It is evident that if such a plate was deeply corrugated or gashed at 17 inches, the depth and percentage of carbon could be regulated and the ridges flattened out in the subsequent forging; moreover, this could be done without the long exposure to a high temperature in the cementation furnace which returns the steel to a condition somewhat akin to that of cast metal. There is an expense connected with the additional heat, but it is saved many times over in the shorter time required for cementation. It would be necessary to make cast iron dies for gashing the plate, but this would be done before bending, and with a single flat die, adapted to all varieties of plates. This expense would be trifling.

Pluck and perseverance are always appreciated, and it is hoped the plate so highly spoken of by Lieutenant Chambers may become as great a success as it deserves to be. One cannot help recalling, however, the way in which the French veteran conjured hot water into nutritious soup. It is true he borrowed a few vegetables and a bone or two from his admiring audience, but then the soup was a wonderful success. It is feared, now that it is found necessary to forge the Chase-Gantt plate down just as much as any other plate, that its great recommendation of cheapness has been lost. Later it is thought that the other ingredients which go so far to make up the cost and uncertainty of manufacture of modern armor will all have to be incorporated. As has already been stated, chromium may be introduced by means of pockets or gashes to any desired depth in a process akin to cementation.

I do not understand the word *absorption* which Lieutenant Chambers has emphasized. Doubtless it may be used either as a generic or specific term. In the latter case, as indicating an inhalation or imbibition without combination, it does not convey a true account of the action which takes place, for it is claimed that the chromium and carbon at the face of the plate are not mere intruders, but actually blended, fused, incorporated, and combined with the cast metal, thus forming a high carbon chrome steel. The generic term is in fact used to describe a specific action which may be more exactly described as that of cementation. The underlying objection to the process is its uncertainty; it also has the defect peculiar to the Harvey process, that is, that in order to get a desired percentage of carbon at the surface it is necessary to run it deeper into the plate than is desired.

The information and corrections which Mr. Wm. Allen Smith, the Secretary of the Harvey Steel Company, has added to the paper are acknowledged with pleasure ; it is to be regretted that he has been unable to discuss the process at length.

Thanks are also again due to the gentlemen who have had the energy to express their convictions either for or against the proposed armor plate.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE U. S. COMMISSION OF FISH AND FISHERIES AND ITS RELATIONS WITH THE UNITED STATES NAVY.

By Commander Z. L. Tanner, U. S. Navy.

In colonial times, and even at a later period, the streams of the Atlantic and Pacific coasts were fully stocked with many species of excellent food fishes which our forefathers firmly believed would furnish to their descendants for all time an abundant and unfailing supply of wholesome and inexpensive food. Yet this unbounded confidence was rudely shaken even as early as the first quarter of the present century, when they discovered that many of the most prolific streams on the Atlantic sea-board were suffering an annual depletion of their most valuable fishes.

The losses were not apparent to the casual observer for years, but they went on steadily and surely until the production became exceedingly limited, and in some cases the fisheries were practically ruined. Spasmodic efforts were made in various localities to remedy this evil, but few systematic and continuous observations were undertaken until the attention of the general government was finally attracted to the imperative necessity of preserving and, if possible, increasing the supply of river, coast, and sea fishes, which are eminently the poor man's food.

The fisheries of the Pacific coast retained their pristine condition until recent times; but, with the rapid increase in population and exceedingly wasteful methods of capture, the necessity for adopting adequate means of preserving the fish supply soon became apparent to the rapidly growing and enterprising communities of the western slope.

Appeals were made to Congress from time to time by men who had given much consideration to the general condition and needs of American fisheries; and, finally, through their continued efforts, supported by eminent scientists, the following law was enacted February 9, 1871:

"There shall be appointed by the President, with the advice and consent of the Senate, from among the civil officers or employees of the government, a Commissioner of Fish and Fisheries, who shall be a person of proved scientific and practical acquaintance with the fishes of the coast, and who shall serve without additional salary.

"Sec. 4396. The Commissioner of Fish and Fisheries shall prosecute investigations and inquiries on this subject, with the view of ascertaining whether any and what diminution in the number of food fishes of the coast and lakes of the United States has taken place; and, if so, to what causes the same is due; and also whether any and what protection, prohibitory, or precautionary measures should be adopted in the premises; and shall report upon the same to Congress.

"Sec. 4397. The heads of the several Executive Departments shall cause to be rendered all necessary and practicable aid to the Commissioner in the prosecution of his investigations and inquiries.

"Sec. 4398. The Commissioner may take or cause to be taken at all times, in the waters of the sea-coast of the United States, where the tide ebbs and flows, and also in the waters of the lakes, such fish or specimens thereof as may in his judgment, from time to time, be needful or proper for the conduct of his duties, any law, custom, or usage, of any State to the contrary notwithstanding." (Rev. Stat. 1878, Sec. 4395.)

Prof. Spencer F. Baird, Assistant Secretary of the Smithsonian Institution, was appointed Commissioner by President Grant on February 25, 1871, and entered at once upon the duties of the office. The provisions of the bill practically limited the choice to him by the clause requiring the Commissioner to serve without compensation. It was a labor of love with him, and he wished to place the position, as far as practicable, beyond the influence of politics, and secure to himself independence of action otherwise unattainable.

The modest sum of $5000 was appropriated for the first year's work; and, although it was inadequate, a creditable showing was made through the hearty co-operation of the Executive Departments and the assistance rendered by a large and efficient corps of volunteers who gave their services without pay in consideration of the superior facilities afforded them for biological research.

In describing the general purposes and methods of the Commission we cannot do better than quote from Prof. G. Brown Goode's essay on "The First Decade of the United States Fish Commission."

The work is naturally divided into three sections:

"1. The systematic investigation of the waters of the United States and the biological and physical problems which they present. The scientific studies of the Commission are based upon a liberal and philosophical interpretation of the law. In making his original plans the Commissioner insisted that to study only the food fishes would be of little importance, and that useful conclusions must needs rest upon a broad foundation of investigation purely scientific in character. The life history of species of economic value should be understood from beginning to end, but no less requisite is it to know the histories of the animals and plants upon which they feed or upon which their food is nourished; the histories of their enemies and friends, and the friends and foes of their enemies and friends, as well as the currents, temperatures, and other physical phenomena of waters in relation to migration, reproduction, and growth. A necessary accompaniment to this division is the amassing of material for research to be stored in the National and other museums for future use.

"2. The investigation of the methods of fisheries, past and present, and the statistics of production and commerce of fishery products. Man being one of the chief destroyers of fish, his influence upon their abundance must be studied. Fishery methods and apparatus must be examined and compared with those of other lands, that the use of those which threaten the destruction of useful fishes may be discouraged, and that those which are inefficient may be replaced by others more serviceable. Statistics of industry and trade must be secured for the use of Congress in making treaties or imposing tariffs, to show to producers the best markets, and to consumers where and with what their needs may be supplied.

"3. The introduction and multiplication of useful food-fishes throughout the country, especially in waters under the jurisdiction of the general government, or those common to several States, none of which might feel willing to make expenditures for the benefit of the others. This work, which was not contemplated when the Commission was established, was first undertaken at the instance of the American Fish Cultural Association, whose representatives induced Congress to make a special appropriation for the purpose. This appropriation has since been renewed every year on a more bountiful scale, and the propagation of fish is at present by far the most extensive branch of the work of the Commission, both in respect to the number of men employed and quantity of money expended."

The plan of operations contemplated the occupation of stations on the Atlantic coast where, in temporary laboratories fitted for the occasion, the corps of specialists would find facilities for the prosecution of their investigations; and, since the fishing interests of the country centered largely on the New England coast, the Commissioner decided to make that region the principal field of operations. The season for active exploration was necessarily restricted to the summer months.

The pioneer station, that of 1871, was at Woods Holl, Massachusetts. Eastport, Maine, was the scene of operations in 1872, and Portland the following year. Noank, Conn., was occupied in 1874, and the wonderfully prolific waters of Woods Holl caused it to be selected again in 1875. The Fish Commission exhibit at the Centennial Exposition prevented the usual field work in 1876. Salem and Halifax were occupied in 1877, Gloucester in 1878, Provincetown in 1879, Newport in 1880; and finally, in 1881, Woods Holl was selected as its permanent summer home, a temporary laboratory being used until the completion of its new station, which was occupied in 1884.

In June, 1871, we find the Commissioner and corps of specialists in their temporary quarters at Woods Holl, the regular routine of a summer station in full operation, including all the various lines of investigation known to naturalists, such as shore-collecting, seining, setting nets and traps for forms not otherwise obtainabie, and exploring the sea bottom with dredge, trawl or tangles.

The surface of the adjacent waters was alive with myriads of minute pelagic forms, embryos of fishes, crabs, worms, ascidians, etc., in masses so dense as to change the color of the water at times, and as their delicate organisms contributed largely to the food supply of the coast fishes, the surface tow-net was frequently brought into requisition for their capture. The temperature of the water and the currents were carefully observed by the officers of the Commission; and, through the co-operation of the Light-House Establishment, Revenue Marine Service, and the Coast Survey, observations were extended along the whole Atlantic sea-board. The specific gravity of the waters of the coast was observed with great care, together with the temperatures and currents, as these data form the basis for the study of the supply of fish food and the migratory habits of anadromous and other fishes. Attention was given to the pollution of streams and adjacent waters by sewage; to the escape of various deleterious substances from manufactories; and to the destruction of fish life caused directly and indirectly by dams, weirs, pounds, and other artificial obstructions. The influence of predaceous fishes on pelagic schools, such as herring, menhaden, mackerel, etc., that periodically visit the coast, was among the most interesting and important branches of inquiry. The predatory habit is developed in many species; but the blue-fish, *Pomatomus saltatrix*, seems to hold undeniable pre-eminence in this respect. Prof. Baird, in his report, said of this marine free-booter:

"No one who has spent a season on the coast, where this fish abounds, can fail to have been struck with its enormous voracity, and the amount of destructiveness which it causes among other kinds of fish. Wherever it appears in large numbers it is sure to produce a marked effect upon the supply of other fishes, either by driving them away from their accustomed haunts or by destroying them in large quantities in any given locality. . . . It is a pelagic or wandering fish, going in immense schools, and characterized by a voracity and bloodthirstiness which, perhaps, has no parallel in the animal kingdom. The fish seems to live only to destroy, and is constantly employed in pursuing and chopping up whatever it can master. As some one has said, it is an animated chopping-machine. Sometimes, among a school of herring or menhaden, thousands of blue-fish will be seen, biting off the tail of one and then another, and leaving in their track the surface of the water covered with the blood and fragments of the mangled fish. . . . If, now, we admit the presence of 100,000,000 blue-fish in the waters referred to, we may form some estimate of the number of fish destroyed by them. To estimate twenty per day as the number destroyed, if not devoured, by each blue-fish, is by no means extravagant."

Accepting the estimate by Prof. Baird of twenty fish eaten or destroyed per day by each of the 100,000,000 blue-fish, and allowing a quarter of a pound average weight for each fish, the destruction would exceed 29,000,000 tons for the 130 days they usually remain on the coast. The destruction of fish life from this cause alone is almost beyond comprehension, and leads irresistibly to the conclusion that Prof. Baird was right when in his report he stated that: "I am inclined to assign to the blue-fish the very first position among the injurious influences that have affected the supply of fishes on the coast."

Commissioner Baird planned from the first to avail himself of the services of volunteers in collecting statistics and general information, and, in accordance with this scheme, thousands of circulars were issued requesting the following information relative to the food fishes of the United States: Name of fish in question in different localities, geographical distribution, size, migrations and movements, relationships, travel, reproduction, diseases, parasites, artificial fish-culture, protection by law, capture, economical value and uses, remarks relative to foreign or domestic allies.

There were eighty-eight questions under these heads, and the replies contained a mass of statements and opinions somewhat inchoate, but nevertheless furnishing a fund of useful information not to be obtained, in the same space of time, by any other method.

A systematic examination of the fishery industries of the great lakes was among the first important investigations instituted by the Commissioner, and the flattering success of operations in that region affords conclusive evidence of the benefits resulting from the scientific explorations and practical work of the Fish Commission.

The co-operation of the Navy Department commenced in a modest way by the loan of a steam launch which was used at the Woods Holl station, during the season of 1871, for dredging and trawling. It was serviceable to the Commissioner also in making his personal inspection of the fisheries of Buzzards bay and Vineyard sound.

In this small way began a naval co-operation in the work of the Commission which has continued without interruption, to the mutual advantage of both these branches of the general government. It steadily increased with the growth of the Commission, keeping pace with its comprehensive scheme of exploration, until finally their relations became much more intimate than is usual between independent departments of the government.

I have aimed to give a general idea of the origin, purposes, and methods of the Fish Commission without entering into detail or even mentioning all of the various branches of biological and physical research included in its scheme of operations. The rapid extension of its work in directions not contemplated at the time it was established not only required an increase in the personnel but involved an unusual amount of experimental work often resulting in the modification of methods to meet changing conditions. Yet the broad principles upon which its wide field of investigations is based remain practically the same.

The friends and advocates of fish-culture view with no little satisfaction the attainment of scientific and practical results far exceeding the anticipations of the most sanguine supporters of the modern application of this ancient industry.

The most notable legislative event in the life of the Commission was the enactment of a law by Congress, at the instance of the American Fish Cultural Association, approved June 10, 1872, providing "for the introduction of shad into the waters of the Pacific States, the Gulf States, and the Mississippi valley, and of salmon, white-fish, and other food-fishes, into the waters of the United States to which they are best adapted." The bill carried an appropriation of $15,000, and required that the work should be done under the direction of the U. S. Fish Commissioner. The artificial propagation and distribution of shad commenced July 2, 1872, and the following year 35,000 shad fry were successfully transported by rail from the Atlantic to the Pacific, and, in the presence of a few prominent citizens, deposited in the Sacramento river at Tehama, California. This attracted no attention except from the few who were directly interested, the people of the coast generally having little faith in the enterprise. Yet, from that apparently small and insignificant beginning the streams of California, Oregon, Washington, and British Columbia are to-day so plentifully stocked with shad that it is quoted lower in the markets of the west coast than in its old home on the Atlantic.

The most interesting feature in connection with the introduction of shad into San Francisco bay is a notable modification of its migratory habits. It is an anadromous species on the Atlantic, visiting fresh-water streams annually for the sole purpose of depositing its spawn, then departing to be seen no more until the next annual period. In its new home it is present the year round in sufficient quantities to insure its being quoted daily in the San Francisco market reports.

The tug Blue Light was detailed by the Navy Department for service under the Commissioner for the season of 1873, and for subsequent years to 1875, and was succeeded by the larger and more commodious Speedwell in 1877. They were specially fitted for the purposes of the Commission, and performed excellent service in dredging, trawling and general exploration. The Speedwell's detail continued through the seasons of 1878 and 1879, the Fish Commission steamer Fish Hawk taking her place in 1880. The construction of this vessel was authorized by act of Congress approved March 3, 1879, and she was built by the Pusey & Jones Company, of Wilmington, Delaware, under the supervision of naval officers. She is a twin screw steamer of 205.7 tons register and 10 knots speed; her hull is of iron sheathed with yellow pine, caulked and coppered. Her equipment included a complete dredging outfit designed for use in depths not exceeding 500 fathoms, and the most complete fish-hatching plant known at that time, capable of handling 7,500,000 shad eggs at one charge. She was successful from the first, and is still in active service. Her anchors and chains were furnished by the Navy Department.

The question of personnel came up when she was near completion, and the Commissioner, feeling that he might possibly be asking too much of the Navy, consulted the Committees of the Senate and House and, with their approval, decided to ask of Congress authority to enlist a sufficient number of men for his vessels, relying upon the Navy Department for officers. The Secretary of the Navy did not approve of the plan, however, and, at a conference with the Commissioner, during which the whole subject was discussed, he said he preferred to furnish officers and men for the vessels of the Commission, for he would then feel that the Department had first mortgage on them, and with their naval organization they would form valuable auxiliaries in case of emergency. He thought the act of February 9, directing heads of Executive Departments to render all practicable and necessary aid to the Commissioner, gave him sufficient authority to act, but a question might be raised in the future, particularly if other vessels were built, hence he thought it advisable to ask Congress to define the status of Fish Commission vessels. This was done through the following act approved May 31st, 1880: "The Secretary of the Navy is hereby directed to place the vessels of the U. S. Fish Commission on the same footing with the Navy Department as those of the U. S. Coast and Geodetic Survey." This law proved mutually satisfactory and still remains in force.

The Fish Hawk was completed too late to participate in fish-hatching operations during the spring of 1880, but she reached the summer station at Newport in time to take an active part in deep-sea exploration. The field of inquiry was extended to and beyond the 100-fathom curve, from 90 to 110 miles south of Martha's Vineyard, where a marvelously rich fauna was discovered, far exceeding in numbers and variety of species any region hitherto explored by the Commission.

The operations of the Fish Hawk, though necessarily confined to depths within 500 fathoms on the steep slope extending from the 100-fathom curve to the ocean bed, had such important results as to demonstrate the necessity of extending the lines far into the ocean depths in order to properly define the habitat and general relations of useful fishes, their friends and enemies, their food, and the friends and foes of species furnishing food to their food. All required extended and systematic investigation only possible with a well-appointed seagoing steamer.

The subjects under consideration on board of the Fish Hawk included all branches of deep-sea exploration capable of prosecution without detriment to the prime object of the cruise, fishery investigation.

One interesting branch of study during the seasons of 1880–81 may be mentioned as illustrative of fishery work. A new species of deep-sea fish made its appearance in large numbers on the Gulf Stream slope in 1879; it resembled the cod in size, general form, texture and flavor, but it was a stranger and would not be admitted to the list of useful fishes until its record was clear on the following points:

1. Is it a food fish?
2. What price will it bring in the market?
3. Can it be taken in paying quantities?
4. What is the best method of capture?

The Commissioner required the following additional information:

1. What is the character of its food, and is it sufficiently plentiful to afford a continuous supply?

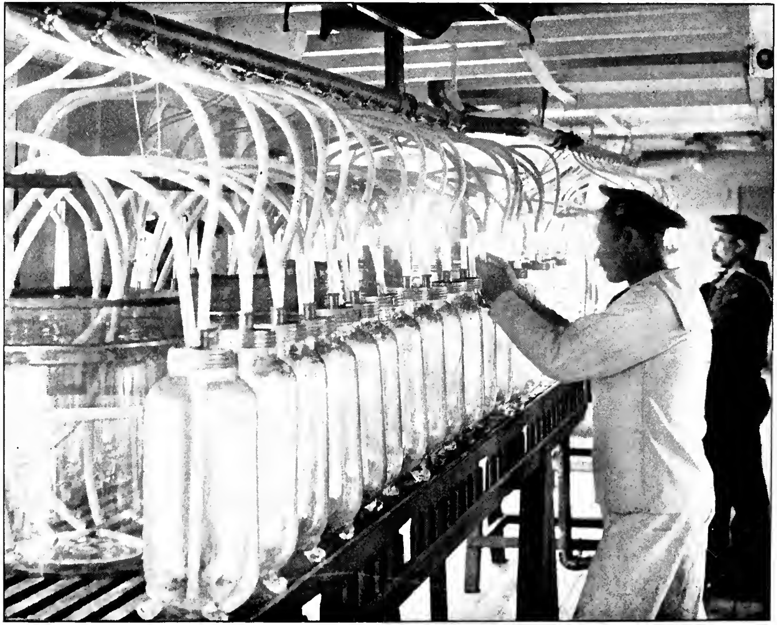
2. What is the character of the sea bottom where the fish is found?

3. What is the temperature of the water at the surface and bottom, the specific gravity, and strength and direction of current?

The ichthyologists of the Commission christened the new species "tilefish" (*Lopholatilus chamæleonticeps*) and upon investigation it was found to be an excellent food fish, its market value approximating to that of cod; it could be taken in paying quantities with hand lines or trawl, and it found an unlimited food supply in the munida and other crustacea with which the region swarmed. The subsequent history of the tilefish is quite as remarkable and mysterious as its first appearance. It had come to stay, apparently, and, its value having been established, preparations were in progress to introduce it into the markets, when, in March, 1882, vessels reaching Atlantic ports from the eastward reported sailing through great numbers of dead and dying fish floating on the surface of the sea, which upon investigation proved to be, with few exceptions, the tilefish.

An officer of the Commission collated the reports from arriving vessels and found the area of floating fish to have been between 5000 and 7000 square miles, the aggregate loss in weight, after reducing the estimates of ship masters to one four-hundredth, reaching the astounding total of 719,360,000 lbs. Nothing more was seen or heard of the species until its appearance in 1893, after an absence of eleven years.

The necessity for a larger vessel for the purposes of deep-sea exploration finally became so imperative that Congress provided for its construction by an act approved March 3, 1881, "for the construction of a steamer for the prosecution of the work and investigations of the Commission of Fish and Fisheries, $103,000." Plans were prepared and bids received for her construction, but



U. S. FISH COMMISSION STEAMER FISH HAWK.

SHAD HATCHING ON THE MAIN DECK.

they all exceeded the appropriation, and consequently nothing more was done until an additional sum of $42,000 was appropriated on March 6, 1882, when competition was again invited, and the contract awarded to The Pusey & Jones Co. for $135,000, exclusive of outfit and special equipment, for which a further sum of $45,000 was appropriated August 7, 1882.

The Navy Department furnished a full outfit of anchors and chains, also a small breech-loading rifle and a number of small-arms, with the necessary equipments and ammunition. Charts, sailing directions, and other less important articles were also supplied.

This vessel, also built under the supervision of naval officers, was launched August 19, 1882, and christened the Albatross. She is an iron twin-screw steamer, 234 feet extreme length, 27½ feet beam, 16¾ feet depth of hold, 1074 tons displacement, and has a maximum speed of 12 knots. She has two masts, brigantine rig, and a sail area of 7521 square feet. Her ordinary coal capacity is 170 tons, which gives her a steaming radius of 3200 miles at a speed of 8 knots, and 4600 miles with her maximum capacity of 240 tons. Her cabin and ward-room are capacious, light, airy and well furnished; the quarters of the crew are unusually comfortable. The apartments of officers and men are heated by steam, and every compartment is artificially ventilated. She is thoroughly lighted by electricity internally and externally, and during the progress of night work the decks are sufficiently illuminated for ordinary purposes by fixed lights, concentration upon any desired point being effected by portable lamps.

The Albatross was specially designed for deep-sea exploration; her chief requisites were strength, sea-worthiness, and the ability to "lay to" with either bow or stern to the wind, with her extremities sufficiently above the dangerous effect of breaking seas to protect delicate apparatus located on poop and forecastle. An easy motion under all circumstances was necessary to the safety of the steel-wire dredge rope.

Her outfit was complete, and her scientific equipment contained the latest and most approved appliances known at the time; also numerous mechanical devices specially designed. Important additions and improvements have been introduced from time to time; in fact, it has been the established policy of the Commission to adopt any device that gave reasonable promise of increasing the safety, economy or efficiency of the vessel.

The Albatross was actively employed on the Atlantic until 1887, her field of operations extending from the Grand Banks of Newfoundland to Nova Scotia, to the bay of Fundy, and the coast of the United States from Maine to the delta of the Mississippi. In the West Indies it embraced nearly the whole of the Caribbean sea, the coasts of Yucatan, Cuba, and the Bahama seas.

Besides her regular biological and physical investigations, she steamed many thousands of miles to discover from whence came the great schools of mackerel, menhaden, bluefish, shad, and other species which annually visit our coast. Search for the lost tilefish was prosecuted from Martha's Vineyard to Cape Hatteras, and the Fish Hawk's lines of deep-sea exploration were extended seaward, midway between the outlying islands of Massachusetts and the Bermudas, when, for the first time in the history of deep-sea exploration, the beam trawl was successfully operated in the great depth of 2949 fathoms.

The schooner Grampus was launched in 1886, and has since been actively employed in her special work. There were various reasons for her construction, the greatest perhaps being the necessity for improvements in the general design and rig of fishing vessels. Speed is a vital element in the ocean fishing vessels of New England, and to economically secure it the tendency has been to build shallow and sharp vessels of great beam which gave them the requisite speed and answered the demands in moderate weather. The center of gravity was, however, carried too high for safety in heavy seas; and in ten years, from 1874 to 1883, inclusive, Gloucester lost eighty-two schooners foundered at sea, with a sacrifice of 895 human lives. The Grampus embodied the best features of our successful schooner yachts and pilot boats, and proved an important object lesson, having effected almost an entire revolution in the form and rig of Gloucester fishing vessels. Her duties have been largely on the fishing banks, among fishermen, introducing improved methods, and studying the present condition of the industry with a view of meeting future wants. She has done some biological work, and made an extended physical examination of the waters of the north Atlantic.

The death of Prof. Baird in 1887 caused many changes in the organization and personnel of the Commission and its relations with other departments of the government. He exercised personal supervision over all branches of the Fish Commission for sixteen years, without pay, giving to this, his labor of love, much valuable time which nature demanded for rest. The rapidly expanding operations of the Commission embraced nearly every State in the Union ; sixteen propagation stations had been established in various localities, producing annually hundreds of millions of young fry which were distributed from Maine to Texas, and the Pacific coast, by three cars specially constructed for the purpose, and several valuable species of foreign fishes had been acclimated and distributed in large numbers. Surveys of the oyster grounds on the Atlantic coast were in progress, and preliminary researches were being made preparatory to the artificial propagation of oysters and lobsters. The great station at Woods Holl had been completed, and the biological and physical researches conducted in its spacious laboratory and on board of the vessels of the Commission were approaching their greatest development.

At the time of his death Prof. Baird was Secretary of the Smithsonian Institution, in charge of the National Museum, and U. S. Commissioner of Fish and Fisheries; the conduct of any of these great institutions, with its attendant responsibilities, being sufficient tax on the energies and strength of one man. Yet they were under his personal administration for years, until finally his magnificent physique and matchless endurance failed, and the end came in the prime of life. The blow fell with all the more severity upon the Commission from his having retained personal direction over all its various branches ; and Dr. G. Brown Goode, who, at the request of the President, assumed the Commissionership *ad interim*, found it necessary to give his immediate attention to the classification of the work and personnel, resulting in the promulgation of regulations, which, with a few unimportant changes, still remain in force. The present scope of the work of the Commission covers (1) the propagation of useful food fishes, including lobsters, oysters and other shellfish, and their distribution to suitable waters ; (2) the inquiry into the causes of the decrease of food fishes in the lakes, rivers, and coast waters of the United States, the study of the waters of the interior in the interest of fish culture, and the investigation of the fishing grounds of the

Atlantic, Gulf, and Pacific coasts, with the view of determining their food resources and the development of the commercial fisheries; (3) the collection and compilation of the statistics of the fisheries and the study of their methods and relations.

Marshall McDonald, the present Commissioner, was appointed by the President in February, 1888. He had been in charge of fish culture and distribution under Prof. Baird, and being familiar with his methods, and the subsequent reorganization effected by Dr. Goode, he assumed his new duties under favorable auspices, and, through his able management, the Commission has steadily enlarged its field of action and general usefulness.

The completion of the Albatross and the results of her first season's exploration of the fishing banks were regarded with much interest by representative men of the Pacific coast, who from that time brought an ever-increasing pressure upon the Commissioner to send a vessel to the west coast to develop their sea fishing grounds, particularly those of Alaska, of which very little was known.

The construction of another vessel for the purpose was suggested, but it was finally decided to send the Albatross after she had made a preliminary examination of eastern waters; and, on the 4th of August, 1886, an appropriation was made by Congress for general repairs and for expenses of the voyage to San Francisco. She sailed from Norfolk, Va., November 20, 1887, with instructions to carry on *en route* such investigations as seemed advisable, considering the limitations of time and appropriation, the 15th of May, 1888, being fixed upon for her arrival in San Francisco.

Few vessels ever left port in better condition or more perfectly equipped; she had a full complement of officers and men, and a large corps of experienced naturalists. The voyage was interesting and instructive, furnishing material for an entertaining volume, but space will not admit of more than passing mention of ports of call and a few leading incidents.

Her first stop was at Santa Lucia, thence to Bahia, Montevideo, Straits of Magellan, and Sandy Point. Nearly a month was given to explorations in the straits and western Patagonian channels; thence to Lota, Panama, the Galapagos, Acapulco, La Paz, and San Francisco, arriving May 11, 1888.

The scientific results of the trip were very satisfactory in spite of the limits imposed; deep-sea investigations and shore collecting were vigorously prosecuted whenever practicable; 42 anchorages were made, the naturalists landing and making collections at 40; 90 dredging stations were occupied in various depths, and 127 soundings were made, some of them exceeding 2000 fathoms in depth. The study of the fishes of different latitudes added much to our knowledge of the distribution of species, and several were found entirely new to science.

The subsequent career of the Albatross in the Pacific, extending over a period of seven years, has been signalized by continuous activity and usefulness. Her summers have been spent in Bering sea and other Alaskan waters; and of the immense area examined by her in that region, 30,000 square miles may be designated as fishing banks on which cod may be found in paying quantities at the proper season of the year.

She explored the fishing grounds south of the peninsula of Alaska during the summer of 1888, extending her operations to the southern California coast later in the season, and finally to the Gulf of California, where a portion of the winter was spent in the investigation of the pearl and other fishing industries.

By direction of the President she conveyed the Senate Committee on Indian Affairs from Puget sound to southeastern Alaska in July, 1889, the remaining summer months being employed in the examination of the coasts of Washington and Oregon. March and April, 1890, were spent in exploring the California coasts, and the remainder of the season in surveying the fishing grounds of Bristol bay and other parts of Bering sea.

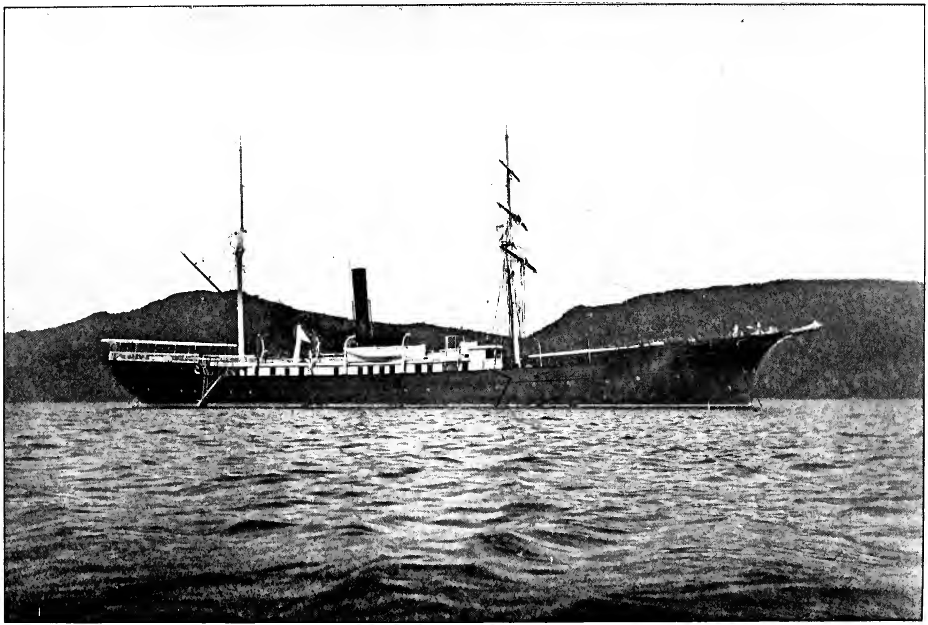
An important scientific expedition, authorized by the President and under the direction of Prof. Agassiz, was sent out the following winter for the purpose of investigating the biological and physical features of an extensive area including the west coast of Mexico, Gulf of Panama, Central and South American coasts to the latitude of the Galapagos, including that interesting group, also the Gulf of California. Returning to San Francisco in May, 1891, the President again diverted her from her usual occupation to carry U. S. Commissioners to the Seal islands in Bering sea, no other vessel being available at the time. The late fall and winter were devoted to the survey of a submarine cable route between the California coast and Honolulu. Two lines were developed and preparations made to run a third when in March, 1892, she returned to the north on seal investigation for the State and Treasury Departments, the field of operations extending from the Straits of Fuca to Prince William sound, the Aleutian chain, and the Commander islands, off the Kamchatka coast.

During the seasons of 1893-94 she was attached to the Bering sea fleet, and performed patrol duty in addition to her special work. The Fish Commission was directed by act of Congress approved March 3, 1893, to make an annual inspection of the seal herd on the Pribyloff islands, and this duty has been performed by details from the scientific corps of the Albatross. Various and important duties which were not contemplated when she was built have thus devolved upon her from time to time, interrupting her regular work. Her cruising grounds extended over the broad area embraced within 60° north and 54° south latitude, and from 34° west to 166° east longitude. She has occupied 1566 dredging stations, made 5043 deep-sea soundings, besides thousands of physical observations not mentioned, and has steamed 164,118 miles.

A brief mention of her more important services to the Navy Department may not be devoid of interest as an illustration of the soundness of the Secretary's estimate of the value of "first mortgage" on a vessel of her class under naval organization.

Her first service under the Navy Department was from January to May 1884, sounding in the Caribbean sea and off the west coast of Cuba, and the examination of the bar at the mouth of the Magdalena river. During the last week of August, 1884, she acted as flagship for the Secretary of the Navy during the autumn manœuvres of the North Atlantic Squadron, taking the place of the Tallapoosa, which had been sunk by collision. From February to May, 1886, while on a cruise to the Bahamas, much deep-sea sounding and other hydrographic work was done for the Navy Department, and later in the same year a line of soundings was run in the North Atlantic at the request of the hydrographer.

Early in 1887 a series of experiments were made at the request of the Bureau of Navigation, relative to the ignition of gunpowder and coal gas by the fracture of an incandescent electric lamp, also a magnetic survey to determine the effect a dynamo in operation has on the compasses of a vessel.



U. S. FISH COMMISSION STEAMER ALBATROSS AT PORT OTWAY, WESTERN PATAGONIA, JANUARY, 1888.

[THE ALBATROSS IS NOW PAINTED WHITE.]

From October, 1891, to February, 1892, she made a cable survey between Monterey bay, California, and Honolulu, sounding two routes, one on a great circle, the other a rhumb line.

From March to August, 1892, although on a special mission under the State and Treasury Departments, she was subject to the orders of the senior officer commanding the Bering sea fleet, and used by him as occasion required.

From May to October, 1893, and again from April to October, 1894, she was attached to the Bering sea fleet under direction of the Navy Department, and did patrol duty in addition to her special work. In the performance of this service the vessel has been transferred temporarily to the Navy Department no less than four times, and retransferred to the Commission, without delay, friction, or changes of any kind occurring in personnel or organization.

It may be mentioned as a further beneficial result of the intimate relations existing between the Commission and the Navy Department, that the latter has been furnished from time to time with valuable hydrographic information, plans of anchorages, charts, and deep-sea soundings from remote and little-known regions, which have been of great service to the Hydrographic Office in the preparation of aids to navigation.

The success attending the general operations of the Commission steadily enlarged its sphere of action and entailed new duties and responsibilities from year to year. The artificial propagation of useful food-fishes is still by far the most important and extensive branch, and there has been a notable increase in the number of species under artificial culture. Among the great triumphs in this direction, if not the most important of all, is the successful and economical propagation of the lobster, which, it is hoped, may largely compensate for the wasteful methods and over-fishing which have been slowly but surely tending towards the extinction of this valuable crustacean.

Additional hatching and distributing stations have been operated on coast and inland waters, and the steamers Albatross and Fish Hawk and the schooner Grampus are actively employed each in its special work.

The gathering and systematic compilation of fishery statistics is an important branch of Commission work. Its officers collected fishery data for the tenth census, and continue to gather complete annual statistics of the fishery industries of the United States, including whaling and sealing.

Without attempting a review of the various operations of the Commission in detail, the following brief synopsis will serve to illustrate its general growth, its present condition, and the practical results attending its operations during the fiscal year ending June 30, 1894.

Fish culture and distribution: hatching stations in operation	21
Number of States in which they are located,	13
Number of species hatched and distributed,	36
Fertilized eggs distributed	19,666,000
Young fry distributed, including 69,066,000 young lobsters	494,253,000
Adult fish distributed	1,921,000
States and Territories in which eggs or fry were deposited	All
Total number of deposits made	3,641

Number of distributing cars, 4; mileage of cars in distributing fish, 105,529; number of railroads furnishing free transportation, 49; number of miles of free transportation furnished by these roads, 65,093.

Floating property: steamers, 2; schooners, 1; steam launches, 9; boats, exclusive of those belonging to vessels, 53.

Naval contingent: officers attached to the Albatross, 9; officers attached to the Fish Hawk, 5; crew of the Albatross, 53; crew of the Fish Hawk, 37.

Commission employees, 170.

Total appropriation for 1894, $352,302.

The notable results of operations during that year, as shown by the preceding summary, are due to the systematic investigations and business-like methods by which the U. S. Fish Commission achieved its marked success and fairly earned its enviable position among the scientific and economic branches of the government.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE HOWELL TORPEDO.

AN ELEMENTARY DESCRIPTION.

By Lieutenant Albert Gleaves, U. S. Navy.

I.

The Howell torpedo is, in dimensions and general appearance, very similar to the Whitehead. Like the Whitehead it carries a war-head containing the explosive charge of gun-cotton, which is rendered operative automatically, during the run, and is exploded by contact with the target.

The Howell shows no trace of itself during its run, but at the end of its course when its buoyancy brings it to the surface, it is readily sighted by the smoke from the calcium-phosphide, a charge of which is placed, for practice runs, in a pocket on top of the torpedo.

The motive power of the Howell is the energy stored up in a fly-wheel, which is spun up to 10,000 revolutions per minute by a steam motor. This wheel weighs about 128 lbs.

The torpedo is distinguished for its great directive power derived from the gyroscopic properties of the fly-wheel.

The shell of the torpedo is made of a hard rolled metal composed of 80 parts of copper, 20 parts zinc, and a trace of lead. The model of 1894 is about 11 feet long and 14.2 inches in diameter. The shell is $\frac{1}{16}$ in. thick. The total weight of the torpedo, including the gun-cotton charge of 100 lbs., is something over 518 lbs. The positive buoyancy of the torpedo is 10 lbs.

The torpedo is divided into three sections, (1) the head; (2) the cylinder; (3) the after section. These sections are joined together by water-tight joints.

1.—THE HEAD.

Practice.—Contains water instead of gun-cotton. A central tube passes through the water tank and carries balance weights to give longitudinal trim.

War.—Contains gun-cotton and the detonator.

The primer of the gun-cotton is contained in a central pocket. The percussion detonator is located in the forward end of the primer case.

The nose contains the firing pin and its mechanism. The firing pin is rendered operative by the action of a small four-bladed propeller on a safety nut.

The nut travels on a thread chased on a pin. Upon entering the water, the safety nut being revolved by the propeller, travels out on the pin until it brings up on the guard on the end of the pin, where it continues to revolve freely.

The construction of the firing mechanism is such that the pin is now operative and upon contact with the target a safety pin is sheared, and the force of the blow, which compresses and trips the firing-spring, causes the firing-pin to strike and explode the detonator.

2.—THE CYLINDER.

Contains the fly-wheel and its gearing, and pockets for depth register and charge of phosphide of calcium.

3.—THE AFTER SECTION.

Contains immersion regulator, impulse movement, immobilizer, and two sections of the shafts. The rear, or tail section, carries the stuffing boxes of the shafts, tiller, and immobilizer rods. The shaft stuffing boxes serve also as thrust-bearings. The rear end of this section is called the tail cone and contains the pitch mechanism and carries the tail frame, fin, rudders, and propellers.

II.

The Howell torpedo has twin-screws driven by the fly-wheel whose axis is at right angles to the longitudinal axis of the torpedo. The propellers have adjustable blades, the pitch of which, by means of the pitch mechanism, is made to constantly change during a run, increasing as the speed of the fly-wheel decreases. The ratio of the propeller revolutions to wheel revolutions is as 4 to 5.

There are two rudders. The horizontal rudder steers the torpedo up or down. The vertical rudder is for the purpose of keeping the torpedo on an even keel, and insures its rectilinear direction in a horizontal plane. "By virtue of the gyroscopic force of the fly-wheel an exterior force acting on the torpedo and having a tendency to direct it from its horizontal course will simply cause the torpedo to roll, and the motion that is then given to the V. R. will cause the torpedo to roll back in the opposite direction, and will eventually bring it to an even keel.

This curious property of the torpedo may be readily exhibited in the shop by spinning up the fly-wheel, and then striking the torpedo a sharp blow on the nose. Instead of moving laterally as might be expected, the torpedo will simply roll over.

The propeller shafts are parallel and are geared with the fly-wheel. The rudders have tiller-rods which extend into the after section, where they are connected with the "impulse movement."

III.—The Immersion Regulator and Impulse Movement.

In the port side of the torpedo, in the after section, is fitted a flat piston. This piston is held in its outward position by the tension of the immersion spring. The tension varies with the depth at which it is desired to run the torpedo, and is set by hand, access to the immersion spring being had on the starboard side.

The principal feature of the immersion regulator is the "angle guide." This device is shown in Figure 1. *S S* are two very light flat springs. The angle guide is mounted on the piston rod in such a manner that when the piston rod moves in or out, the angle guide will be tipped one way or the other. It is connected with the H. R. pendulum by an adjustable lever.

The H. R. pendulum swings on a knife edge fixed in the bracket at the top of the torpedo. The V. R. pendulum is located on the port side of the torpedo.

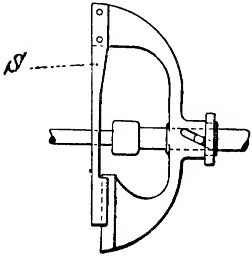


Fig. 1.

It is by the swing of the H. R. pendulum when the torpedo is diving or ascending, and by the motion of the piston when the torpedo is above or below the set depth, that the position of the angle guide is determined, which thereupon transmits, by means of the impulsive movement, the proper throw to the H. R.

Movement of the piston will tip the angle guide, so also will movement of the H. R. pendulum, and the latter dominates the force exerted by the piston, as will be seen later on.

The mechanism of the impulse movements consists of two racks *T T* (see Fig. 2) sliding in a frame with reciprocal motion simultaneously approaching each other and receding. The motion is derived from two eccentrics which themselves take motion through gearings from worms on both shafts. These impulses are very rapid, usually 4½ per second; the number depending, of course, upon the speed of the shaft, and are continuous as long as the shaft revolves.

These movements or impulses act upon the rudder in this way: The tiller rods have attached to them the little arms or "pallets," *P P* (Fig. 2). These pallets are pivoted at the center. On one end is a pin upon which rest the light springs of the "angle guide."

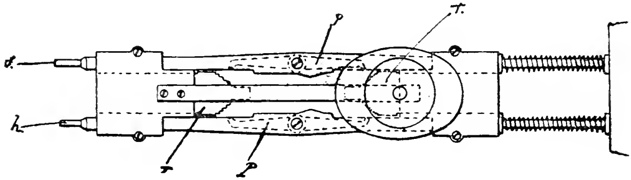


FIG. 2.

When the angle guide is tipped by the motion of either the piston or H. R. pendulum, or both, acting together or against each other, the pallet will also be tipped and the toe of the pallet coming in the path of the rapidly moving impulse rack will engage the teeth on the rack, and thus the tiller rod be pushed either forward or to the rear, transmitting motion to the horizontal or diving rudder. In a similar way the V. R. pendulum actuates an adjustable V. R. angle guide, to control the V. R. pallet in reference to the upper impulse racks.

It is clear that as long as the torpedo is moving at set depth with its horizontal axis in the plane of the horizon, the pallets also will be in the same plane, and the impulse racks will travel to and fro without coming into contact with them. There will be no move of either piston or pendulum.

Suppose, however, the torpedo is *above* the set depth. The pressure on piston being less than spring tension, the piston will be set out, the angle guide will tip and engage the forward end of the pallet with the impulse rack, and produce a certain amount of *down* rudder, causing the torpedo to dive. The pendulum then swings forward, and in doing so tips the angle guide in the opposite direction, which engages the *after* end of the pallet in the impulse rack, causing *up* rudder, thus checking the dive. The pendulum's influence being thus greater than that of the piston, this result is obtained, otherwise the torpedo would continue to dive.

If the torpedo is *below* set depth and approaching it, the reverse action takes place.

IV. The "immobilizer" is a rod which has longitudinal motion given by the pitch frame. It holds the pendulum forward or back as desired (when the torpedo is launched) a short interval of time, about two or three seconds perhaps. It will be seen that by holding the H. R. pendulum forward, the angle guide will tip the after end of the pallet to engage the impulse rack, thus producing up rudder. In this way the torpedo's dive is checked. The H. R. pendulum is automatically released at the set time.

V. The torpedo is ejected from the tube (above water) by a 5 to 6-oz. charge of black powder, this being sufficient to throw the torpedo clear of the ship's side.

VI. The fly wheel is spun up by means of a small steam motor which is readily disconnected from the torpedo. The energy in the wheel at 10,000 revolutions per minute is equal to 500,000 ft. pounds, and it requires 30 horse power for one minute to *store* it, but it requires only ¼ H. P. to keep the wheel at 10,000 *after* it has been spun up.

The range of the torpedo is 800 yards; its speed over 400 yards 26 knots. This is the maximum yet attained with the torpedo of 14.2 inches diameter.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MARCH 21, 1895.

LIEUTENANT COMMANDER B. F. TILLEY, U. S. Navy, in the chair.

THE SOLAROMETER; A MODERN NAVIGATING INSTRUMENT.

By LIEUTENANT W. H. BEEHLER, U. S. Navy.

The great progress that has been made in naval architecture and marine steam engineering demands improvement in the instruments for navigating the magnificent products of human ingenuity as exemplified in the modern men-of-war.

The solarometer claims to meet this demand by providing a method of making astronomical observations independent of the visibility of the sea horizon.

The primary object of the solarometer is this feature of its artificial horizon, which is so combined with the astronomical values of declination, hour angle, azimuth and altitude in relation to the observer's latitude and zenith that all the elements of the nautical astronomical problems are solved.

The mechanical solution of the problem as in the solarometer becomes more of a practical necessity as a result of hourly opportunities to astronomically determine the ship's position and compass errors; not because of any defects in the mathematical computations from altitude by the sextant, but in order to save the time these calculations involve.

If observations were taken once or twice every hour, they would involve a total of from six to eight hours daily work with sextant, alidades and logarithms to obtain the results of those observations, and this total time would be so distributed throughout the 24 hours that there would be very few spare minutes left for the navigator to do anything else than observe and calculate the results of his observations.

The solarometer obviates elaborate logarithmic calculations and combines in itself a pelorus; so that it furnishes a complete solution of the entire problem to ascertain ship's position and compass errors in the space of time ordinarily required to observe the altitude by the sextant and take its bearing with a pelorus.

The general principles upon which the solarometer is constructed may be concisely stated to consist of a series of circles representing the nautical astronomical triangle supported upon a constant level base which locates the position of the observer's zenith in that triangle.

There is a definite relation between all the five quantities of declination, latitude, hour angle, altitude, and azimuth, such that with each and every variation of the value of one or more of these quantities, the others have corresponding values. The variations of all these quantities cause an infinite variety of possible values to the astronomical triangle, and all are beautifully illustrated by the solarometer.

The Nautical Almanac gives the right ascension and declination of a heavenly body on a circle which passes through the poles. The book of azimuth tables for the same time and place gives the position of the same body or a circle which passes through the observer's zenith. These two publications give the exact position of the same body on two different circles for the same time and place. If the body is on two circles at the same time it must be at their intersection, and if a telescope be fixed at this intersection of the circles representing those of the astronomical triangle, it follows that a body cannot be seen in the axis of that telescope without making this system of circles show the hour angle, elevation of the pole and azimuth, or the observer's longitude, latitude and the ship's compass errors.

This is not a new principle in astronomy but merely a novel point of view, involving a mechanical movement in unison of two variable systems of coordinates, viz.: declination and hour angle, with latitude and azimuth, having their junction marked by the body's zenith distance or altitude. The axis of the telescope lies in the radius of the concentric circles, and that radius makes an angle with the artificial horizon equal to the altitude of the body observed. This mechanical arrangement of the circles is such that the movement in unison of the declination circle around the poles with the azimuth circle around the zenith makes the axis of the telescope follow the apparent path of the heavenly body observed in the sky from its rising, to the meridian, to setting.

The solarometer is an instrument mounted on a constant level base so arranged that the motion of the ship will not be communicated to the instrument. The constant level base consists of a metal stand about 30 inches in diameter and 4 feet high, with openings underneath to admit an electric storage battery and other implements. On top within the stand there is supported a large

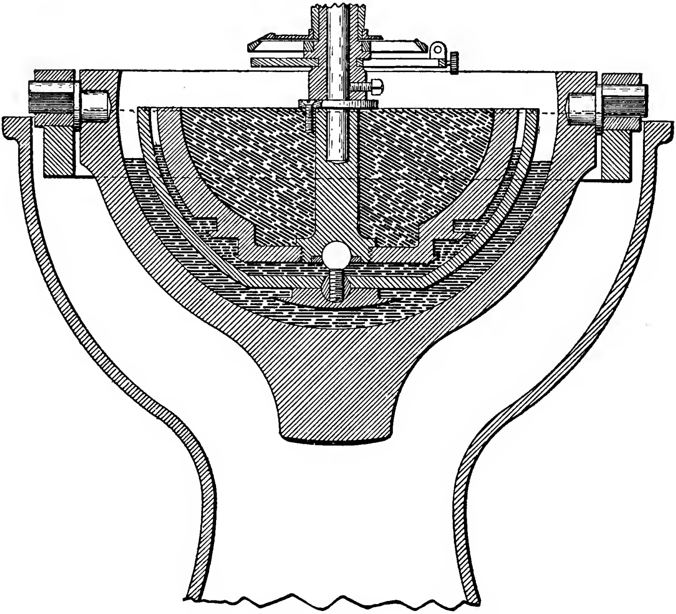


FIG. 1.—Section of standing bowls, float and mercury.

cast iron bowl on gimbals with a forged steel ring. The cast iron bowl is hemispherical. The bottom of the bowl has an extra mass of metal cast with it so as to make it swing on its gimbals with a pendulum effect. The bowl is lined with porcelain and contains mercury and a float. The float is made in two parts and consists of two cast iron bowls, concentric hemispheres. The inner bowl is filled with lead and carries a steel column, rigidly secured at the centre of the bottom of the float and accurately fitted at right-angles to the flat surface of the bottom of the inner float. This steel column projects three inches above the horizontal plane of the top of the bowl. In the center of the bottom of the inner float there is a small spherical recess to admit the ball of a ball-and-socket bolt by which the two bowls constituting the compound float are joined. The bottom of the outer bowl of the compound float is also flat and has a socket in its center to admit the lower ball of the ball-and-socket bolt. The bottom part of this socket is closed by a wrought iron plate whose exterior surface completes the spherical shape of the bottom of the compound float leaving a rectangular horizontal space in the bottom. There are two sets of horizontal rectangular spaces in the sides of the inner bowl of the compound float. All of these horizontal rectangular spaces in the different parts of the compound float are made accurately at right angles to the steel column in the center of the inner bowl, with the object of securing a horizontal flotation of the compound float in the mercury and carrying the steel column absolutely vertical. The instrument is carried upon the steel column.

The experience with the solarometer on the American mail steamer New York has demonstrated that this arrangement of the compound float will not operate on board of high powered vessels, where the vibrations are excessive. In the North German Lloyd steamer Weimar all the vibrations were compensated by this arrangement of floats united together by a ball-and-socket bolt.

The object of making this compound float was to increase the weight of the float by the mercury it contained and to compensate for the vibrations that might be communicated to the mercury in the outer bowl.

It was plainly evident that when the mercury in the outer bowl was agitated as much as the surface of water when boiling the various impulses coming from the agitated mercury were communicated to the inner bowl and gave that bowl a tendency to move in all directions at the same time, and it therefore did not move in any. Any one who agitated the surface of the mercury in the outer bowl would see that the mercury in the inner bowl was not disturbed, and be convinced.

But these concerned only the effect of the vibrations horizontally while the effect vertically remained to be seen by actual experience when mounted on a high powered steamer with excessive vibrations.

By examination and experience on board of the steamer New York on a run from New York to Newport News, on January 20, 1895, the vertical vibrations were found to be communicated to the float with double effect.

The impulses vertically upward appear to be fully annulled by freely rising against the air, but the impulses downward instead of meeting each other in their course along the curved spherical sides of the float and bowls and becoming neutralized, because equal and opposite, met the ball-and-socket bolt and imparted motion to it.

The ball-and-socket bolt was more or less inclined from the vertical and the vibrating impulses coming down on one side met that bolt sooner than those which came down on the opposite side. This bolt then received the successive shocks on one side and alternately received the shocks on the opposite sides. The bolt then communicated all these shocks to the float with double the effect.

These shocks were irregular and made it impossible to determine when the sun or star was in the axis of the telescope for a period of 20 seconds of time.

The ball-and-socket bolt was removed, the vibrations were absorbed and the objects seen in the telescope no longer jumped across the field of view. Before the bolt was removed the inner float had a constant tendency to revolve in the bowl so that the bolt, upon receiving these vertical pressures, acted somewhat like a rudder.

The special function of the ball-and-socket bolt is obtained by small balls or rubber tubing floating on the surface of the mercury. Larger balls are also floated upon the mercury of the outer bowl. These balls keep the float and inner bowl nearly concentric; they do not carry any of the shocks due to the vibrations and they avoid the sudden send of the float when the ship strikes a huge wave in a heavy sea. The ball-and-socket bolt will no longer be used.

This arrangement of the float in the gimballed bowl provides not only for preventing the motion of the ship from being communicated to the instrument, but also insures the instrument being carried absolutely vertical. The gimballed support of the outer bowl and its pendulum motion compensates for most of the motion due to the rolling and pitching of the ship. The vibrations caused by the throbbing of the engines are absorbed by the mercury in the inner bowl.

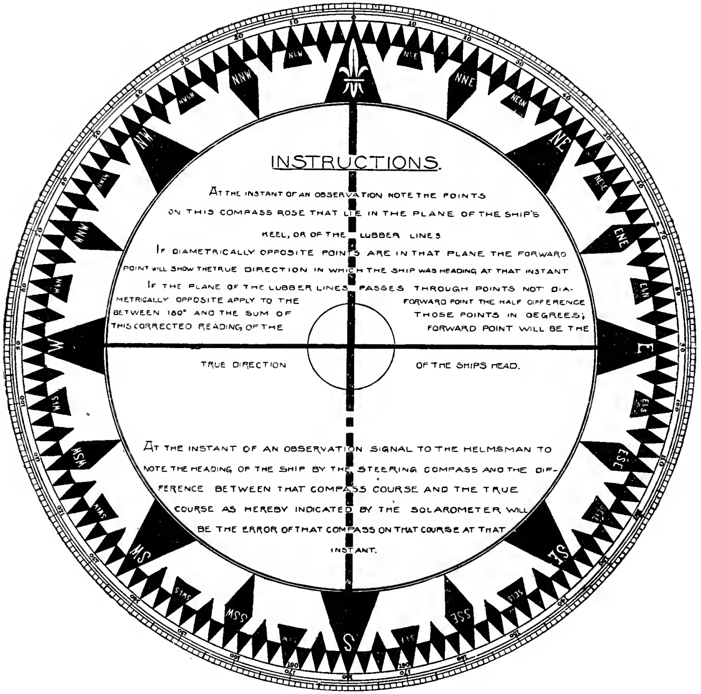
The principle involved by using a float in mercury is that which Prof. Michelson used in his apparatus to determine the velocity of light. He claims that the truest level that can be obtained under any circumstances for accurate astronomical work is that secured by floating a block of granite in a tank of mercury.

The float is free to move about in the mercury. The top surface of the inner part of the float is covered with a compass-rose, marked to quarter points and graduated in degrees from zero at north to 180 degrees south in each hemisphere. The top edge of the outer bowl is marked with lubber lines indicating the plane of the ship's keel. At these two points in the plane of the keel of the ship, or parallel therewith, are two pointers, which are hinged and lightly rest upon the compass-rose to indicate the direction in which the ship is headed.

As the compass-rose on the inner float will be carried about so that its center will rarely ever be exactly coincident with the center of the bowl, it is necessary to note the position of the pointers of the lubber line and transfer the plane of the lubber line to the plane passing through the center of the float as is explained by reference to the diagram of the compass-rose which contains the following instructions: "At the instant of an observation, note the points of the compass-rose that lie in the plane of the ship's keel, or of the lubber line.

"If diametrically opposite points are in that plane, the forward point will show the true direction in which the ship is heading at that instant. If the plane of the lubber line passes through points not diametrically opposite, apply to the forward point the half difference between 180 degrees and the sum of those points in degrees. This corrected reading of the forward point will be the true direction of the ship's head."

Owing to the peculiar notation of the degrees on this compass rose constantly increasing from zero to 180 degrees from left to right, and then decreasing to 170 degrees on the other side, there is an apparent exception to the rule. For instance, in case the



INSTRUCTIONS.

AT THE INSTANT OF AN OBSERVATION NOTE THE POINTS ON THIS COMPASS ROSE THAT LIE IN THE PLANE OF THE SHIP'S KEEL, OR OF THE LUBBER LINES

IF DIAMETRICALLY OPPOSITE POINTS ARE IN THAT PLANE THE FORWARD POINT WILL SHOW THE TRUE DIRECTION IN WHICH THE SHIP WAS HEADING AT THAT INSTANT

IF THE PLANE OF THE LUBBER LINES PASSES THROUGH POINTS NOT DIAMETRICALLY OPPOSITE APPLY TO THE FORWARD POINT THE HALF DIFFERENCE BETWEEN 180° AND THE SUM OF THOSE POINTS IN DEGREES; THIS CORRECTED READING OF THE FORWARD POINT WILL BE THE TRUE DIRECTION OF THE SHIPS HEAD.

AT THE INSTANT OF AN OBSERVATION SIGNAL TO THE HELMSMAN TO NOTE THE HEADING OF THE SHIP BY THE STEERING COMPASS AND THE DIFFERENCE BETWEEN THAT COMPASS COURSE AND THE TRUE COURSE AS HEREBY INDICATED BY THE SOLAROMETER WILL BE THE ERROR OF THAT COMPASS ON THAT COURSE AT THAT INSTANT.

FIG. 2.—The compass-rose of the Solarometer at the instant of an observation of the sun or a star has its north point exactly in the direction of the true north.

lubber line should pass through a line north 10 degrees east and north 175 degrees east, the half difference between 180 degrees and the sum of these two points would be 2½ degrees; and the forward reading would be north 7½ degrees east, and the after reading would be north 177½ degrees east. These are evidently not diametrically opposite points. In this and similar cases, where the plane of the lubber line runs nearly north and south, one point should be read north so many degrees east, and the other north so many degrees west, or in this instance one would be read north 10 degrees east and the other north 185 degrees west, and according to the rule, half the difference between 180 and 195 degrees, or 7½ degrees, would give the ship's head; in this case, north 2½ east. The compass-rose has the figure 190 on the inner circle opposite 170, to indicate where the notation should be greater than 180 degrees, and the rule given on the compass-rose is thus made to apply under all circumstances.

The spherical shape of the bowls and float has a beneficial effect in compensating for the motion of the ship. The rolling and pitching makes the bowl move around the mercury. The weight of the mass of mercury, its consequent inertia, and the almost frictionless contact it makes with the porcelain surfaces tend still further to keep the mercury at rest. The shape of the displaced volume of mercury in the outer bowl is spherical, no matter how the bowl may move around the mass of mercury, and hence all currents that might be otherwise set up in the mercury are obviated, and the use of mercury is peculiarly well adapted for this purpose. It must be remembered that the bulk of the motion of the ship is compensated by the gimballed support of the bowl, and the percentage of that motion remaining to be compensated by the mercury is very small.

The only motion of the ship that cannot be compensated is that due to yawing or bad steering. Practice at sea, however, will soon enable an observer to follow that motion by swinging the float correspondingly. With the vibrations due to the engines there is an effect upon the observer's eye which causes the image of the body observed to oscillate slowly in the field of the telescope. In the American Line steamer New York the solarometer was mounted on a light steel deck within six feet of a windlass on the same deck. The vibrations of that deck when that windlass was in operation were extremely violent, but the image of the sun's disc always remained perfectly clear and well defined, but the disc moved about ⅛ of its diameter back and forth across the cross-hairs in the telescope, requiring a little judgment to determine when the disc was in the axis of the telescope. On one occasion, in the U. S. S. Montgomery, a simple float without the extra bowl and inner mercury was used, and then the vibrations of the engines at times made the sun's disc so indistinct that it could not be observed.

In taking observations, the float is necessarily disturbed by handling the instrument, but it soon comes to rest, and the evidence that it is at rest is plain from the observation of the heavenly body at rest in the telescope. In the first designs of the instrument, the horizon circle had eight spirit-level bulbs counter-sunk in the metal, but the inertia of the spirit bulbs was such that they continued to oscillate after the body observed was seen to be perfectly at rest in the telescope.

The instrument mounted on the constant level base consists of five circles with a supporting bracket and a telescope. The five circles represent the meridian, equator, declination, horizon, and latitude.

The meridian circle *M* and the equatorial circle *E* are joined rigidly at right angles to each other, and each has a pair of trunnions at points 90 degrees from their junctions. A hemispherical bracket *A*, with a hollow cylindrical sleeve, fits on the vertical spindle of the float and has bearing plates in its upper extremities to receive the trunnions of the equatorial circle *E*. These bearings are adjustable vertically and laterally by means of adjusting screws underneath and on the side of the bearing blocks. The trunnions of the equatorial circle *E* are diametrically opposite at 6 hours or 90 degrees from the plane of the meridian circle. It is graduated into hours, minutes, and to 30 seconds of time from zero to 12 hours on each side of the meridian.

One of the equatorial trunnions is hollow to admit a tube that projects inward and carries two horizontal arms with vernier plates to lie against the graduated surface of the meridian circle *M*. A pendant arm is attached to the outer end of the tube carrying these verniers, and has near its lower end bearings against two adjusting screws fixed within the frame of the supporting bracket *A*. On the opposite side there is a vise-clamp to secure the trunnion of the equatorial circle *E* in any fixed position. A pendant arm on this trunnion fits in between the frame of the bracket *A*, and abuts against a spring and micrometer screw to permit small movement of the clamped trunnion and to accurately set the equatorial and meridian circles to any desired elevation of the pole of the meridian circle *M*.

The meridian circle *M* is graduated to degrees, minutes and seconds of arc, from zero to 90 degrees in each quadrant.

The declination circle *D* is concentric with the meridian circle *M* and revolves on the trunnions at the poles around the equatorial circle *E*. This circle is graduated into degrees, minutes and seconds of arc. It carries a covering ring that supports the opposing verniers on the graduated face of the declination circle. A sliding block on the circle carries the verniers 180 degrees apart. A block with set screw and tangent screw permits accurate setting of the declination verniers at any desired point. The graduations are from zero at the equator to 90 degrees at the poles.

In the radial plane of the zero of the upper declination vernier block there is a socket tube which receives a pendant pin from the telescope block on the bracket *K*.

The declination circle revolves around the poles of the meridian circle and over the face of the graduated equatorial circle *E*. Two verniers are attached to the sides of the declination circle, on opposite side of the equatorial circle. These verniers fit close to the graduations of the equatorial circle and enable those graduations to be read to one second of time. The notation of the graduated equatorial circle is such that the zero of the vernier on one side of the declination circle comes opposite the mark for 12 hours when the vertical plane passes through the meridian circle and the common center of all. The numerical notation of the graduation is simply slewed around to accommodate the space required for the metal of the declination circle.

A graduated horizon circle is attached to the bottom of the cylindrical sleeve of the supporting bracket *A*. Above this circle a hemispherical bracket *B* revolves around that sleeve and carries two flat arms with opposing vernier plates to move over the graduations of the horizontal circle *Z*. The upper extremities of the hemispherical bracket *B* have bearing shafts supporting the hemispherical bracket *K* which revolves vertically from the horizon to the zenith, at the same time that the supporting bracket *B* revolves around the horizon circle *Z* at the bottom of the instrument.

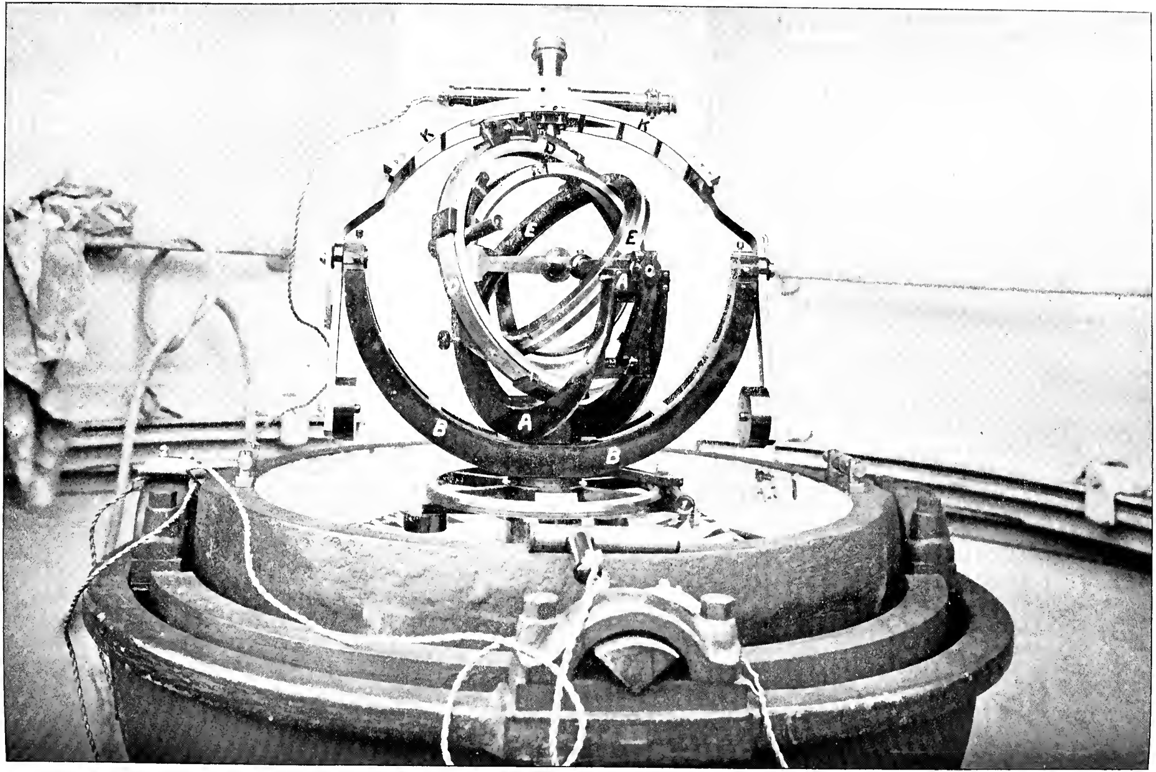


FIG. 3.

A block containing a right prism is centered in the telescope bracket *K* in the radial plane of the common center of all the system of circles. The block has three circular openings for the tubes of the telescope. One tube having the object lens

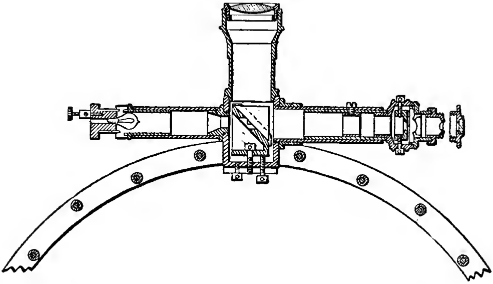


FIG. 4.—Section of the telescope showing the manner in which the sun or star observed is refracted by the right prism into the eye piece. Also shows the shade glass that fits over the eye piece. The miniature electric lamp in the left tube throws its light diffused through the prism and illuminates the field of the cross hairs near the eye piece.

has its axis accurately fitted in the radial plane of the concentric circles. A second tube at right angles to the first and adjustable carries the eye piece and reticule of cross-hairs. The tube can be focused for observations of the sun and stars. The eye piece can be fitted with adjustable shade glasses and a spiral slotway focuses the reticule of cross-hairs in the eye piece. A third tube at right angles to the first and on the opposite side of the circle carries a small incandescent electric light of $\frac{1}{2}$ candle power, 4 volts and one ampère. This electric lamp is in a tube with ventilating holes and a frosted glass shade to send a diffused light through the prism across to the reticule of cross-hairs, which is illuminated without affecting the clear visibility of the star that is being observed. A sliding rheostat in the circuit of the lamp controls the degree of illumination. Underneath the telescope block in the radial plane of the axis of the telescope there is a pendant pin that fits in the socket tube of the vernier block of the declination circle *D*. This pendant pin is in the radial plane of the axis of the telescope and the common center of all the circles. The tube of the telescope and the pendant pin are all fitted with adjusting screws to be mounted accurately.

At one of the poles there is a clamp screw and micrometer screw which confines the declination circle in any position. A clamp and micrometer screw are also attached to the revolving sleeve at the bottom of the hemispherical bracket *B*, so that this bracket may be accurately confined at any desired position in azimuth. A clinometer is attached to one of the compensating weighted arms of the telescope bracket *K*. This clinometer is graduated to degrees and merely serves to indicate the approximate altitude of the body observed, for the purpose of making allowance for the refraction of the atmosphere. The horizon circle at the bottom is not concentric with the other circles, but is parallel to the horizontal plane which passes through the comon center of all the circles.

In one of the first designs of the solarometer, this horizon or azimuth circle was placed in the horizontal plane of the center of the concentric circles. In that design, the vertical circle passing through the zenith was a hemispherical arc supported by sliding shoes on the horizontal circle. It carried the telescope block which moved in altitude by sliding up and down on that circle. This has been replaced by the telescope bracket *K*, which occupies a position at right angles to that formerly occupied by the vertical circle. This obviates the friction of the block moving up and down the vertical circle, and also obviates the friction of the sliding shoes on the horizon circle. The former movement is replaced by the shaft bearings of the bracket arm *B*, and the latter movement by the revolution of that bracket *B* on the sleeve. The original design was a more perfect representation of the actual conditions of the astronomical problem. The substitution affords a better mechanical arrangement.

The union of the several concentric circles capable of moving in unison around their own shaft bearings produces a peculiar series of motions that can only be clearly understood by an examination of the instrument in all its positions. The movement of the bracket *B* in azimuth causes the declination circle to revolve around the pole while the telescope bracket revolves in altitude in its shaft bearings and around the pendant pin of the declination vernier block. Four different revolutions are thus involved, ma-

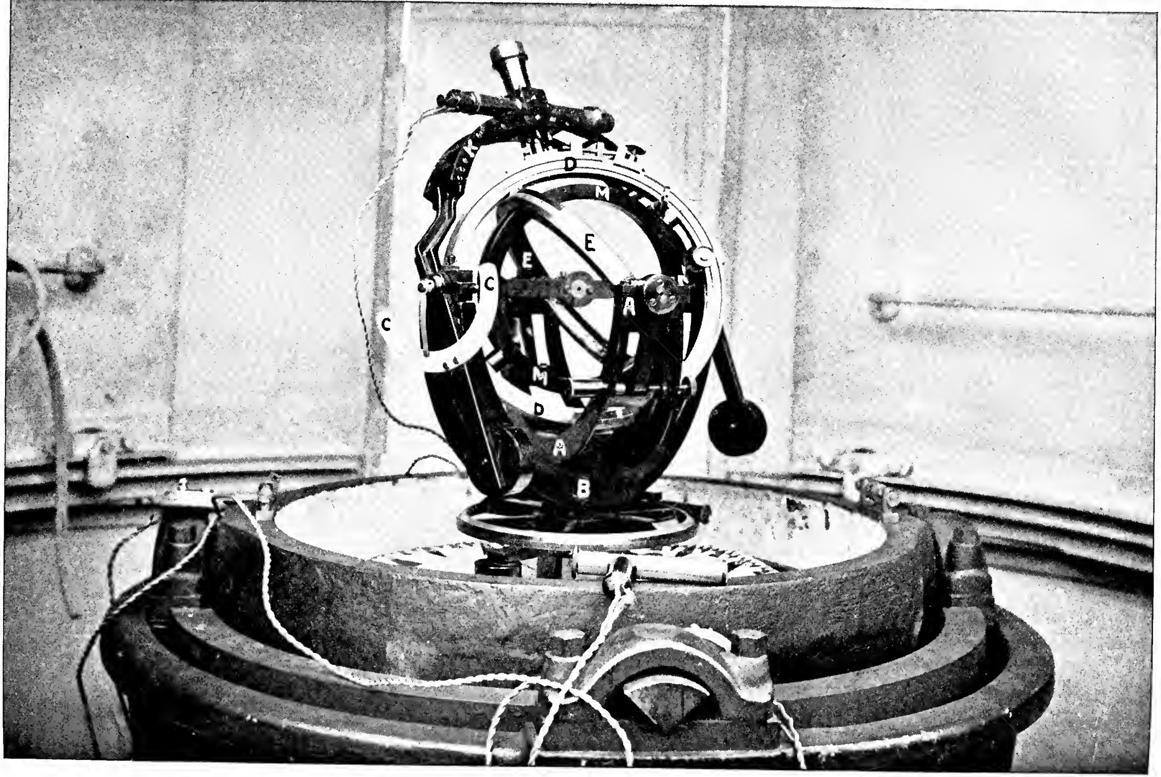


FIG. 5.

king the several circles combine to cause the axis of the telescope in its motion to point and follow the apparent path of the heavenly body that may be observed in the sky.

All the bearings and movable parts of the instrument are adjustable. All the graduations are on silver, and each circle has opposing verniers, so that if there be any eccentricity it may be eliminated by taking the mean of the readings of the two verniers.

The circles are made of composition gun-metal ; they are channel-barred with strengthening blocks at junctions. The instrument is as light as possible consistent with the requisite strength for durability.

In the earlier designs, the instruments were made of alloyed aluminum. Different alloys were tried and none were found to be suitable. At sea the aluminum seemed to absorb salt from the air ; at least small white crystals were found on the rings every day, while none could be seen on the yellow metal of certain parts. The oxidization of aluminum is white, and these crystals may have been particles of oxidized aluminum, but they had a salty taste, were easily removed, and were found in greater quantities at sea than in port away from the sea air. The hard silver aluminum alloy was also found to be too soft for the bearings, and it was necessary to bouch the bearings in that metal in the shop after the limited use of the instrument for observations in Fauth & Co's yard in Washington. Experiments were made with various aluminum alloys in a simple salt water bath, and after three months in the bath they were pitted as much as a zinc rod in a Le Clanchè cell, with a year's service. This experience has conclusively demonstrated the worthlessness of such alloys of aluminum as were tried, for any instrument of precision. The weight of the solarometer made of aluminum alloy was 21 pounds, or only 7 pounds less than the weight of the present channel-barred composition gun-metal instrument.

In making the broad statement that an observer can accurately determine a vessel's position and compass error by the solarometer at all hours when anything is visible in the sky, there are certain limitations. It is not claimed that anything can be done with the solarometer which may not be solved by mathematics.

In observing bodies on the prime vertical when the effect of an error in the latitude has but little or no apparent effect on the computed hour angle, it will be extremely difficult to find the latitude by the solarometer at such a time, and in the same manner the time and azimuth will be extremely difficult to determine accurately by observations of a body crossing the meridian near the zenith.

As the solarometer must be supported at some point on the equatorial or meridian circle, it has been found to be least disadvantageous to support it at six hours from the meridian. These supports prevent observations from being taken at these hour-angles, but as the altitudes will be low and the effect of refraction large, the time is unfavorable.

But these limitations do not apply if the body is at any appreciable distance from those directions, and the times when the observations of visible bodies are not advantageous are comparatively so few that, generally speaking, the broad statement ought to be admitted.

To use the instrument the observer has a chronometer regulated to Greenwich mean time, a nautical almanac, book of azimuth tables, refraction tables, and blank record books with forms for observations of the sun and stars.

METHOD OF OBSERVING.

For Observations of the Sun.—Find in the nautical almanac the sun's declination and equation of time for the Greenwich time of the observation, adjust the vernier of the declination circle *D* to the declination for the Greenwich apparent time. Set the latitude vernier to the approximate latitude of the place. Point the telescope to the sun by revolving the telescope arm and bracket to its altitude, and swing the float in the bowl, to find the sun's disc in the axis of the telescope. The axis of the telescope should be set a little west of the sun, and the instrument allowed to come to rest on its float while waiting for the sun to move westward in azimuth and altitude to appear in the exact axis of the telescope. Note the time by chronometer (or watch compared with the chronometer regulated to Greenwich mean time) the instant the sun is in the axis of the telescope. The arrangement of cross hairs circumscribing the sun's disc enables the observer to readily determine when the center of the sun's disc is exactly in the axis of the telescope. At the same instant the position of the pointers in the plane of the lubber line must be noted on the compass-rose of the float. Read the hour angle and azimuth to record the observation.

OBSERVATION OF THE SUN.

North German Lloyd S. S. Weimar.

Observer, Mr. C. Nahrath, 2d Officer. Date, *August* 19, 1894.

	h.	m.	s.
Chronometer,	5	02	12
Watch,	1	15	0
Chronometer—Watch,	3	47	12

	m.	s.
Chronometer Error,	—3	42
Change by Rate,		—1
Chronometer Correction,	—3	43

Sun's Declination, N.			H. D.
°	′	″	″
12	42	28	—49
	—4	5	5
12	38	23	—245

Equation of Time,		H. D.
m.	s.	s.
3	26.7	—.58
	—2.9	5
3	24	—2.90

	h.	m.	s.
Watch Time,	1	21	44
Chronometer—Watch,	3	47	12
Chronometer Time,	5	8	56
Chronometer Correction,		—3	43
Greenwich Mean Time,	5	5	13
Equation of Time,		—3	24
Gr'nw'h Apparent Time,	5	1	49
Local Apparent Time,	1	24	52
Longitude,	3	36	57
	°	′	″
Longitude in Arc,	54	14	15

Remarks :

Forward Index A = N 80° E.

After Index B = N 110° W.

2) — 10 = 180 — 190

—5 + A = N 75° E = True Course.

N 80° E Comp's Course.

5° Comp's Error.

Values by Solarometer.				By Tables.		
		°	′		°	′
Latitude,		40	58		40	58
	°	′	″	°	′	″
Declination,	12	38	23	12	38	23
	h.	m.	s.	h.	m.	s.
Hour Angle,	1	24	52	1	24	52
	°	′		°	′	
Azimuth,	140	40	W	140	40	W

State of Weather, Pleasant. Wind Direction and Force, N. W. 5.
State of the Sea, Smooth. Degrees of Roll each Way, 4. Pitching, 2.
Visibility of Sea Horizon, Clear.
Ship's Position by Dead Reckoning: *Latitude*, 40° 58′ N. *Longitude*, 54° 18′ W.
Ship's Position by Sextant: *Latitude*, 40° 58′ N. *Longitude*, 54° 15′ W.

This observation with an assumed latitude is a correct altitude of the sun's center, but the hour angle would be in error corresponding to the error in the assumed latitude, precisely as in an ordinary time sight taken with a sextant if worked with an erroneous latitude. When the latitude is not known, it is therefore necessary to take a series of observations to determine both the latitude and hour angle, or the true local apparent time. Proceed then to take a second observation, setting the latitude 10, 20, or 30 minutes (according to the amount in which the latitude may be in doubt) north of the latitude used at the first observation, and take a second observation as before, noting the chronometer time, hour angle and azimuth for record. After recording, take a third observation, setting the latitude 10, 20, or 30 minutes south (according to the amount in which the latitude of the first observation may be in doubt) of the latitude used in the first observation, note the chronometer time, the position of the pointers of the lubber line at the instant of the observation, and read the hour angle and azimuth for record. The three observations with these different latitudes must then be compared to determine the true latitude.

Take the difference between the chronometer times of the first and second observations and the difference between the solarometer hour angles of those observations; find the second difference between these two intervals.

Take the difference between the chronometer times of the first and third observations and the difference between the solarometer hour angles of those observations; find the second difference between these two intervals.

Take the difference between the latitudes of the second and third observations, or the difference between the extreme latitudes used.

We then have the proportion that, as the sum of the second differences is to the second difference of the first and second observations, so is the extreme difference between the latitudes used to the correction to be applied to the latitude used for the second observation. Similarly as the sum of the second differences is to the second difference of the first and third observations, so is the extreme difference of latitude used to the correction to be applied to the latitude used in the third observation.

Each of these proportions will give the true latitude. Proceed to take a fourth observation, using the true latitude thus found to find the true hour angle. In every case note the change in latitude due to the ship's run in the interval of observing and make proper allowance for that change.

The following series of three observations by the solarometer will explain this subject clearly.

	Chronometer Time.	Hour Angles.	Latitude used.
1st observation....	10 h. 7 m. 35 s.	11 h. 21 m. 20 s.	38° 55′ N.
2d observation....	10 h. 10 m. 19 s.	11 h. 28 m. 30 s.	39° 10′ N.
3d observation....	10 h. 14 m. 57 s.	11 h. 22 m. 5 s.	38° 30′ N.

Comparing the first and second observations, the difference between chronometer times equals 2 m., 44 s., or 164 s., and that of the hour angles equals 7 m., 10 s., or 430 s.; the difference between these intervals is 430 s. — 164 s., or 266 s.

Comparing the first and third observations, the difference between chronometer times equals 7 m. 22 s., or 442 s.; that between the hour angles 45 s.; and the difference between these intervals is 442 s. — 45 s., or 397 s. The sum of the second-differences is $266 + 397 = 663$.

We have then the proportion that, as the sum of the second differences is to the difference of intervals of the first and second observations, so is the difference between the highest and lowest latitude used to the correction to be applied to the latitude used in the second observation; or, as the sum of the second-differences is to the difference in the intervals of the first and third observations, so is the difference between the highest and lowest latitudes used to the correction to be applied to the latitude used in the third observation.

In this example we have the two proportions, viz.:

$663 : 266 = 40 : 16'$; and $39° \ 10' - 16' = 38° \ 54'$.

$663 : 397 = 40 : 24'$; and $38° \ 30' + 24 = 38° \ 54'$.

In this example, the latitude used in the first example was nearly correct, and it will be noticed that when, as in the second observation, the latitude was too high, the difference between the solarometer hour angles was greater than that between the chronometer times. And again, when the latitude used is lower than the true latitude, as in the third observation, the difference between the solarometer hour angles is less than that between the chronometer times.

It follows as a rule that in any series of observations of the same body, if the difference between the solarometer hour angles is greater than that between the chronometer times the latitude used is too high; and if the difference between the solarometer hour angles is less than that between the chronometer times the latitude used is too low.

By keeping this rule in mind, a skillful observer will soon be able to discover error in the assumed latitude and find the correct latitude and the corresponding correct hour angle readily.

Having found the latitude, take a fourth observation with that latitude and find the hour angle as before, which will be the exact local time. These four observations, which can with practice readily be taken in 10 or 15 minutes, determine with an accuracy within two miles the observer's latitude and local apparent time, and hence his longitude; and by comparing the compass course at the instant of the last observation with that indicated by the lubber line on the compass-rose of the solarometer, the error of the compass on that course will be accurately ascertained.

This method of determining the latitude and hour angle is based upon the fact that by the movement of the telescope in altitude and azimuth, the altitude is affected by the elevation of the the pole and the distance of the telescope from the meridian. If the latitude is too high or too low, the movement of the telescope will not follow the plane of the path of the movement of the body in the sky, but will incline thereto, either higher or lower, according to the error in the elevation of the pole, or the latitude used, and the differences between the chronometer time interval and the solarometer time interval, indicated by the hour angles, show the deviation of the movement of the telescope from the plane of the path of the body in the sky.

Another method for determining the latitude and hour angle is to take one observation with an assumed latitude, and then take a second observation at five or ten minutes later; if the hour angles differ exactly five or ten minutes, then the assumed latitude is the true latitude. If they differ unequally, set the latitude north or south accordingly; take a third observation, and five or ten minutes later take a fourth observation; if the chronometer time intervals and the difference between the hour angles of the third and fourth observations are the same, the latitude last used is correct, and so is likewise the hour angle of the last observation. If the chronometer time intervals and hour angle intervals of the third and fourth observations do not correspond, correct the latitude again, corresponding to the difference, and take two more observations, and proceed in this manner until both the latitude and hour angle are correctly obtained.

In taking and reading the observations, the opposing verniers should generally both be read. If there is any discrepancy between the readings of the two opposing verniers on the same circle, the mean of the two must be taken to eliminate any eccentricity caused by dust, etc., in the bearings around which the circles revolve.

In taking observations of the sun at low altitudes, it is necessary to allow for refraction. A clinometer is attached to one prolonged arm of the telescope bracket *K* to indicate the angular altitude of the axis of the telescope. Refraction causes the sun to appear higher than it really is, and the observer should observe the center of the sun in its true position and not in the position where it appears elevated by the refraction of the atmosphere. Tables showing the effect of refraction at various altitudes are given in the books of navigation, but in observing with the solarometer the observer may apply this correction in the altitude when observing, and to do this, he must observe a star or the center of the sun's disc as much below the axis of the telescope as the refraction makes it appear above its true altitude. The small central square in the axis of the telescope is a square whose dimensions are equal to two minutes and forty seconds (2′ 40″), which is the refraction for an altitude of 20 degrees. One half of that space is the refraction for 36 degrees, and two spaces would be the refraction for an altitude of 10 degrees. The clinometer shows the altitude approximately; and, with practice, a skillful observer can allow for the effect of refraction at different altitudes and varying conditions of the atmosphere.

This method of observing the sun or a star as much below the axis of the telescope as the refracted rays of light make it appear above its true position is theoretically correct, but it is difficult to introduce into practice.

When the amount of the refraction is known, it is much more difficult to allow for it than to observe the body exactly in the axis of the telescope, and the effect of neglecting or accurately allowing for the refraction is much greater than is generally supposed. The habit of applying refraction to observed sextant altitudes is so fixed that the effect of neglecting it has not been generally considered by practical men.

Tables are in preparation showing the effect of refraction on the hour angle at different altitudes for different latitudes and polar distances. These tables have so far been completed only for the latitudes of the transatlantic steamer routes, and they show regularity in the decreasing error of the hour angle up to within a certain azimuth, when the error begins to increase and reaches a second maximum close to the meridian.

This peculiarity is explained by the fact that the change in altitude is greatest on or near the prime vertical, and that when on or near the meridian, it takes the body much longer to change its altitude by the small amount of the refraction, than when nearer the prime vertical to change very much more in altitude.

The table for a latitude of 40 degrees north, polar distance of 100 degrees, shows an error of 30 seconds in time at an altitude of 10 degrees, when the hour angle read from the solarometer was 4 hrs., 31 min., 8 sec., without allowing for refraction of 5′ 20″, azimuth 112° 33′ instead of 112° 29′. At an altitude of 20 degrees, azimuth 123° 5′, the hour angle was 16 seconds too small. At an altitude of 30 degrees, azimuth 138° 11′, the hour angle was 12 seconds too small. At greater altitudes the error in the hour angle began to increase until at an altitude of 39 degrees, azimuth 166° 14′, it was 18 seconds too small; 43 min., 22 sec., from the meridian instead of 43 min., 40 sec. The error in hour angle near the meridian is much greater and in a measure indeterminate.

Observations for time, on or near the meridian are not reliable, especially under these circumstances, and the effect of refraction must then be considered almost entirely upon the latitude.

By setting the declination at a polar distance decreased by the refraction multiplied by the cosine of the hour angle, a fair degree of accuracy will be obtained by observing the body in the axis of the telescope to find the latitude on or near the meridian.

In using these tables, the observer notes the chronometer time when the body is exactly in the axis of the telescope and the position of the plane of the lubber line on the compass-rose. He then reads the azimuth, hour angle, and altitude from the clinometer attached, and corrects the hour angle for the refraction according to the correction given in the tables. He then sets the declination circle to the correct hour angle and finds the true azimuth corresponding thereto from the azimuth circle. The difference between the azimuth observed and the correct azimuth must be applied to the compass-rose to find the corrected heading of the ship.

In finding both latitude and longitude from a series of observations by second differences, each of the observations should be corrected and second differences worked from the corrected hour angles to find the true latitude, as explained.

The effect of parallax is so small that it is ignored in observations by the solarometer; observations of the moon are not recommended on account of its horizontal parallax.

OBSERVATIONS OF STARS.

For observations of stars, a small electric lamp shining through frosted glass, illuminates the cross hairs in the eye-piece without affecting the clear visibility of the star in the telescope. The magnifying power of the telescope is such that the usual bright navigational stars are clearly distinguishable, more so than with the naked eye.

OBSERVATION OF ALTAIR.

North German Lloyd S. S. Weimar.

Observer, Lieutenant W. H. Beehler, U. S. N. Date, *August* 26, 1894.

	h.	m.	s.		m.	s
Chronometer,	9	52	10	Chronometer Error,	—3	45
Watch,	4	45	0	Rate,		—1
Chronometer—Watch,	5	7	10	Chronometer Correction,	—3	46

*'s Right Ascension,			*'s Declination,			Right Ascension, Mean Sun.		
h.	m.	s.	°	′	″	h.	m.	s.
19	44	40	+8	35	22	10	18	53.2
							1	48
						10	20	41

	h.	m.	s.
Watch Time,	5	56	25
Comparison,	5	7	10
Chronometer Time,	11	3	35
Chronometer Correction,		—3	46
Greenwich Mean Time,	10	59	49
Local Mean Time,	10	47	7
Longitude in Time,		12	42
	°	′	″
Longitude in Arc,	3	10	30

	h.	m.	s.
*'s Hour Angle,	1	23	8 W.
*'s Right Ascension,	19	44	40
R. A. Meridian,	21	7	48
R. A. Mean Sun,	10	20	41
Local Mean Time,	10	47	7

	Values by Solarometer.			By Tables.		
	°	′	″	°	′	″
Declination,	8	35	22	8	35	22
Latitude,	50	9	45	50	9	45
	h.	m.	s.	h.	m.	s.
Hour Angle,	1	23	8	1	23	8
	°	′		°	′	
Azimuth	150	10		150	11	

Forward Index A = N 85° E.
After Index B = N 89° W.
2) +6 = 180 — 174
3 + A = N 88° E = True Course.
N 114° E Comp's Course.
26° Comp's Error.

State of Weather, Pleasant. Wind direction and Force, S. W. 5.
State of Sea, Smooth. Degrees of Roll Each Way, 2. Pitch, 1.
Visibility of Sea Horizon, Undefined.
Ship's Position by Dead Reckoning: *Latitude*, 50° 10′. *Longitude*, 3° 08′.
Ship's Position by Sextant or Bearing: *Latitude*, ... *Longitude*, ...

For observations of a star, find in the Nautical Almanac the star's right ascension and declination, and the right ascension of the mean sun, all of which are to be corrected for the Greenwich time of the observation. Set the declination vernier on the declination circle *D* to the declination of the star, and the latitude vernier to the approximate latitude of the observer. Revolve the telescope in altitude and azimuth, and find the star in the axis of the telescope in the same manner as described for observations of the sun. When the latitude is not known, take a series of observations in the same manner as described for observations of the sun.

The facility with which a star can be found in the field of the telescope is remarkable. It is much easier to find the star to be observed in the field of the telescope than to point a spy-glass to see a star when standing on land, especially if the declination circle is set to the approximate hour angle.

To read the arcs with facility, a small hand telescope is provided in which there is a side tube containing a miniature electric lamp, which throws a light from within the reading telescope through its object lens on the vernier, which is thereby clearly illuminated.

In recording the observations, the four quantities—declination, latitude, hour angle, and azimuth—as read from the solarometer should be compared with those same four quantities in the book of azimuth tables, enlarged and extended. If there is exact correspondence between the observed four quantities read from the solarometer and those computed in the book of azimuth tables, the observer has positive proof that his result is accurate.

For observations of Polaris, or the polar star, note the right ascension and declination of Polaris in the Nautical Almanac, and see if the right ascension is such that the star is above or below the pole. If the star is above the pole, set the declination circle vernier at the north declination 88° 44′ 15″. But if the star is below the pole, set the declination vernier at its sub-polar declination, 91° 15′ 45″, or as given in the Almanac.

If the star's hour angle is not approximately known, it may be readily ascertained by adding the right ascension of the mean sun (as given in the Almanac and corrected for the Greenwich mean time) to the approximate local mean time to find the right ascension of the meridian; then add or subtract the star's right ascension from the right ascension of the meridian to get the star's hour angle.

As the declination circle revolves on the polar axis the observer must not attempt to revolve the declination circle by means of the telescope bracket or the azimuth clamp when the telescope is clamped by the declination set-screw near the pole. In this position the change in azimuth can be but very small, and the leverage of the telescope bracket is liable to throw the instrument out of adjustment. Any change in hour angle with the telescope near the pole must be made by turning the declination circle in hour angle directly, and allowing the movement of the declination circle to move the telescope bracket *B* in azimuth.

The clamp screw which sets the declination circle at any hour angle ought not to be used for any observations; it is provided for use in adjusting the instrument, and should not be used when taking observations.

Having set the declination of Polaris on the solarometer, and the latitude vernier to the observer's approximate latitude, put the declination circle to the approximate hour angle of Polaris and turn the telescope by swinging the float horizontally until the star is seen in the field of the telescope. Bring the star in the axis of the telescope by working the micrometer screw of the latitude clamp. This will give the altitude of Polaris, and, since the position of the declination circle in hour angle mechanically causes the pole of the solarometer to be as much elevated or depressed from the altitude of the north pole as the star's position in its path around the north pole deviates from the north pole, the pole of the solarometer will have the same elevation as the true north pole, and the vernier on the meridian circle will show the observer's true latitude.

Observations of Polaris by the solarometer have invariably been found to be exact, much more so than any meridian altitude of the sun by a sextant. It is claimed that a good observation of Polaris under favorable conditions will give the true latitude within one mile. Observations of Polaris where cross bearings of lighthouses were available, as in the Chesapeake bay, invariably indicated the latitude as accurately as those by cross bearings, and agreed perfectly.

DETAILS OF MANUFACTURE AND ADJUSTMENT.

In the manufacture of the solarometer all the circles are turned on the lathe and are made absolutely concentric. The equatorial circle *E* and the meridian circle *M*, after being securely united together at right angles to each other are revolved in the same lathe. These circles are graduated after they have been thoroughly tested to be concentric and accurately at right angles to each other. They are placed in the adjustable bearings on the hemispherical bracket *A* and fitted on the lathe. The declination circle is fitted on its polar trunnions and adjusted to revolve around its polar bearings, exactly concentric with the meridian and equatorial circle. The telescope supporting arm *B* is placed on the shaft under the hemispherical bracket *B* and adjusted to revolve concentrically around that shaft. The azimuth circle is fixed rigidly on the bottom of the shaft under these brackets and adjusted to be accurately in the horizontal plane at right angles to the vertical axis passing through the common center of the rings. The telescope bracket is fitted in its bearings on the ends of the hemispherical arm *B* in the horizontal plane passing through the common center of all the rings. The telescope block with its projecting pendant pin is fitted into the socket tube on the declination vernier block, and the telescope block is centered in the telescope bracket *K*. All parts are thus assembled and ready for final accurate adjustment.

APPURTENANCES.

Each solarometer is furnished with a set of implements, viz.:

First.—A reading telescope to be held in the hand. This is designed to be held close to the eye and close to the vernier to be read, and its magnifying power is such that the fine graduations of the verniers are clearly legible and sharply defined. It is made of aluminum and can be readily cleansed. For use at night, a small tube is set in on one side at an angle opening towards the object lens. This tube contains a miniature electric lamp of 1 candle power, 4 volts, and requires 1 ampère current. A small aluminum shield is set in the main tube of the reading telescope and prevents the electric light from being thrown into the observer's eye. The light clearly illuminates the vernier and enables it to be read with even better facility than by daylight; under circumstances, the observer will find it advantageous to use the electric light in day time. The arrangement is such that the lamp and its shield do not interfere with its use by daylight. All verniers are accessible to the reading telescope in all the various positions of the different circles.

Second.—Two miniature electric lamps are furnished for reserve supply in case of breakage.

Third.—A striding level to fit upon the bearings of the hemispherical arm *A* is furnished for use in adjusting the instrument, to see if it is carried absolutely vertically upon the float.

Fourth.—One spare set of spider cross hairs, and one reticule of cross lines engraved on glass. These reticules are not to be inserted or adjusted unless the vessel's position is accurately established. Though exceedingly delicate, it is rare that it will be necessary to use the spare reticules.

Fifth.—Two shade glasses, which fit over the eye-piece for the observations of the sun.

Sixth.—One screw-driver.

Seventh.—Two small steel capstan bars for making adjustments.

Eighth.—Two electric storage batteries, with suitable lengths of insulated conducting wire, switches, etc. One of these batteries is to be kept underneath, within the stand of the base. The other battery is charged and kept in reserve to replace the one in use within the stand when exhausted.

ADJUSTMENTS.

First.—Adjust the bearings of the equatorial circle *E* on the adjustable bearing on the horizontal plane of the hemispherical bracket *A*. The equatorial circle is placed horizontally, and the meridian circle exactly vertical. The bearings are adjusted with the equatorial circle perfectly horizontal, by means of the adjusting screws.

Second.—Clamp the declination circle *D* accurately in the vertical plane of the meridian circle. Loosen the latitude vise clamp *V* on the hemispherical bracket *A* and revolve the three circles *E*, *M*, and *D*, together in the bearings of the equatorial ring. In revolving, the declination circle *D* must always remain in the vertical plane of the meridian circle *M*, and it is so adjusted.

Third.—Place the declination circle in the plane of the meridian circle *M* with the pin of the telescope set in the declination vernier socket and adjust the telescope block so that the axis of the telescope is equidistant from the bearings of the telescope bracket *K* on the supporting hemispherical arm *B*. Loosen the declination clamp screw and revolve the telescope in altitude from the horizontal plane to the vertical and the horizontal plane on the opposite side, adjusting any deviation of the axis of the telescope from the vertical plane of the meridian circle.

Fourth.—Set the azimuth circle with its opposing verniers at zero and 180 degrees, loosen the declination clamp, and revolve the telescope in altitude, and adjust the bearings for any deviation of the hour angle from the plane of the meridian circle. The declination circle must, in this case, remain in the plane of the meridian circle, though unconfined. Any deviation will be corrected by adjusting the height of the telescope bracket bearings.

Fifth.—Point the telescope to a distant fixed point, and adjust its axes by revolving the loosened verniers and latitude clamps for various positions in the plane of the meridian circle *M*.

Sixth.—Place the instrument upon a level stand on a pier, put the axis of the telescope in the zenith of the instrument. A collimating tube with a cross hair is fixed above the instrument in the vertical plane of the axis of the center of the instrument. By looking in the eye-piece of the telescope, the collimating wire must appear in the center of the cross-hairs in all positions in which the arm *B* may be revolved.*

Seventh.—The circles are set at every 10 degrees of latitude and declination, and every 10 minutes of hour angle; and for all the various positions which the azimuth circle will occupy due to these combinations, the azimuth must coincide with the computed azimuth in the book of azimuth tables.

Eighth.—The instrument is mounted on a solid pier and observations are made of the heavenly bodies, and adjustments tested.

Ninth.—The instrument is next placed upon the float and se-

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*The instruments made by Fauth & Co., Washington, D. C., were adjusted by this firm in the manner described. The sixth adjustment is a very ingenious and satisfactory method devised by this firm, and great credit is due them for the skillful and accurate workmanship of the solarometers they have made.

cured thereon, with the plane passing through the zero and 180 degree points of the azimuth circle, exactly coincident with the plane passing through the north and south points of the compass-rose on the float. A striding level is put upon the recesses in the hemispherical bracket *A* and the instrument is revolved in different positions in azimuth and altitude to determine if it is thoroughly counterbalanced in all of its parts, and is carried absolutely vertical by the float.

Tenth.—The instrument is finally mounted on its constant level base and tested by taking observations of the sun and stars at different declinations to determine the longitude and latitude of the observer, in the yard at Fauth & Co.'s works. The result must be exact.

In the manufacture of the stand, bowls and floats, careful and accurate mechanical workmanship is also requisite. The bearing blocks of hardened steel are accurately fitted, and the forged steel ring and bowl are accurately balanced on their gimballed bearings.*

After the float is floated in the mercury the level flotation is tested by a sensitive spirit level centered on the spindle on which the instrument is mounted. The float swimming in the mercury is revolved, and after it ceases to oscillate the bulb of the long spirit level must come to perfect rest while the float continues spinning in the mercury perfectly horizontal. The long sensitive spirit level is placed in all positions in different horizontal planes on the spindle that supports the instrument, and the level flotation of the float is tested in all positions both at rest and when spinning freely in the plane. All the floats are adjusted to meet these requirements and the accuracy of the constant level base is established beyond all doubt.

Whenever the float is touched by the hands the level flotation is necessarily disturbed, but it comes back with remarkable celerity.

Actual experience is necessary to convince many of the fact that the motions of the ship are thoroughly compensated by the constant level base. When a huge wave strikes the ship, the float will be by its inertia thrown with some degree of violence against the sides of the bowl, but experience thus far obtained has shown that this rarely happens and only interferes with observing for a

*The bases, bowls, floats, and observatory houses were made by the Detrick & Harvey Machine Co., of Baltimore.

brief interval. The motion due to yawing and bad steering cannot be compensated; the helmsman should be cautioned to keep the ship steady on her course and much of that motion will usually be avoided. Any navigator will have no difficulty on this account, since all such yawing will necessarily be so limited that the heavenly body will not be lost to view in the field of the telescope, and an observer can easily judge by the regularity of the oscillations of the heavenly body when it is in the axis of the telescope. Such judgment is equally necessary in observations with a sextant and much more difficult than with the solarometer, whose cross hairs enable the observer to judge this with facility and accuracy.

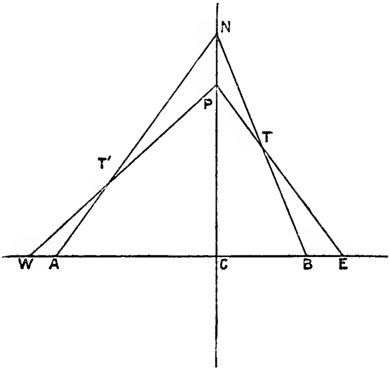
On board the U. S. Cruiser San Francisco the solarometer, after having been adjusted, was raised from its spindle and a fresh compass-rose placed on top of the float. It was subsequently found to be out of adjustment, and the results of a great many observations obtained by Lieutenant A. Ward and other officers, while agreeing uniformly within a few seconds, were about 2 minutes and 18 seconds in error in longitude, and with this difference that the longitude given by the forenoon observations was too far east by two minutes and 18 seconds, while the longitude by the afternoon observations was too far west by the same amount.

The error arose either because the instrument did not set vertically, or the arms of the latitude verniers were not horizontal. The striding level is furnished with each solarometer to determine if the instrument is properly carried on the float, but upon examination this spirit bulb had become useless on account of the evaporation of the alcohol from an almost invisible crack in the graduated glass tube.

As the San Francisco was about to sail for Europe and the striding level could not be replaced in Newport, the horizontal latitude verniers were adjusted by the amount of the error in the latitude ascertained by a meridian altitude of the sun.

The error in the latitude illustrates the well known effect of error in latitude on the longitude, and at the same time demonstrates the accuracy of the instrument and its thorough accordance with the mathematical principles.

In the sketch let the line *WA CB E* represent the equator, the line *NP C* the meridian, the lines *P T E* and *P T′ W* the plane of the declination circle with the pole at its proper elevation, and the lines *N T B* and *N T′ A* the plane of the declination circle of the solarometer out of adjustment, having the pole at *N* instead of being at *P*. The true hour angles were *C P E* and *CP W* for forenoon and afternoon observations. The solarometer out of adjustment gave those hour angles as *CNB* and *CNA*. *T* and *T′* indicate the altitudes of the sun at those observations.



The longitude at anchor at Newport being 4 h. 45 m. 19 s., and taking the observations, they had in the forenoon :

G. App't time,	2 h. 53 m. 09 s.	instead of	G. App't time,	2 h. 53 m. 09 s.
L. App't time,	10 h. 10 m. 08 s.		L. App't time,	10 h. 07 m. 50 s.
Long. by Sol.,	4 h. 43 m. 01 s.		True longitude,	4 h. 45 m. 19 s.

And in the afternoon :

G. App't time,	7 h. 50 m. 09 s.	instead of	G. App't time,	7 h. 50 m. 09 s.
L. App't time,	3 h. 02 m. 32 s.		L. App't time,	3 h. 04 m. 50 s.
Long. by Sol.,	4 h. 47 m. 37 s.		True longitude,	4 h. 45 m. 19 s.

The error in the elevation of the pole having caused this difference in the longitudes on different sides of the meridian. This effect is the same as that upon which Table XXXVIII of Bowditch is calculated ; the effect of an error of one minute in the latitude upon the longitude.

In order to obtain accurate results, it is necessary to read the graduations and verniers accurately. If any of the circles are set carelessly and erroneously, it is absurd to expect correct results with any instrument of precision.

The instrument is, when once mounted, kept on its base constantly available for observations. It is not carried about, and therefore the most frequent cause of damage to instruments is obviated. Intelligent handling of the instrument to take observations cannot injure it, and its durability under these conditions is assured much more than is that of instruments which are packed in boxes and carried about after having been used.

THE SOLAROMETER DECK OBSERVATORY.

In order to protect the instrument from the wind and weather, and enable observations to be taken under all conditions of rolling and pitching at sea, a peculiar observatory is provided as shown in the illustration. This observatory consists of a sheet-metal cylinder six feet in diameter and twelve inches high, which is screwed by wood screws to the deck. The upper part consists of two parts joined together. The lower part is a cylinder six feet in diameter, fitted with rollers and clips to revolve on top of the concentric cylinder secured to the deck. This is three feet high and six feet in diameter. Upon this cylinder the upper part is supported. The upper cylinder is cylindrical, five feet in diameter, three feet high, with a flat conical top. The upper part sets with one of its surfaces in the vertical plane of the lower cylinder, so that the center of the upper cylindrical part is six inches in rear of the center of the lower cylinders. A door is made to fit in the rear surface of the two upper parts. To get inside, it is necessary for the observer to step over the lower cylinder that is secured to the deck. The front hemispherical section of the upper part is fitted with two movable shutters, which can be closed entirely or opened to any extent up to 180 degrees. On the ledge in front of the opening there is an adjustable wind screen which is three feet wide and eighteen inches high, fitted with two curved bracket arms so that it may be adjusted to any position from the vertical to the horizontal. Within the observatory, under the ledge, beneath the wind screen, there is a box to contain books and implements. The electric storage battery to furnish the light for the telescope and to read the circles is stowed within the stand of the instrument. The arrangement of the observatory permits an observer to observe a heavenly body that is abeam, with the ship rolling and the wind from abeam, so that the wind screen will protect the instrument from being heeled over out of the vertical plane, and the top of the observatory will not obscure the body being observed. Or in case the body to be observed is ahead, and the wind is ahead, while the ship is rolling deeply, the wind screen will protect the instrument from the wind, and the opening of the shutters will prevent the body from being obscured by the sides of the observatory. In this house, which can be revolved so that a body can be observed in any direction from the ship, the instrument is always available for observations.

In the U. S. S. San Francisco, the solarometer has a peculiar cover of the same dimensions as the top of the base. It is made to open at the top and drop down and rest on the rim of the base, and to turn on rollers around the top, using one of the hemispherical lids of the top for a wind screen.

This arrangement is much smaller than the regular deck observatory, but is inadequate when there is any wind. In the solarometer observatory, the observer may enter and close the door and when he opens the sliding wings of the slit there is no draught of wind blowing through, and no effect of the wind upon the instrument.

The primary object of the navy is to train officers and men to fight the ships in time of war, but while training, much useful hydrographic and meteorological work has been done by the navy, and such work will always be done in time of peace.

The solarometer will be found to be a most useful aid in such utilitarian work. For surveying coasts, investigations of ocean currents, running lines of sounding in surveys and for ocean cables, and every phase of scientific research so well done by the navy, it is evident that the solarometer meets a demand for accurately locating the ship's position and compass error astronomically at all hours of the day or night, independent of the visibility of the sea horizon.

PRECAUTIONS TO BE OBSERVED IN USING THE SOLAROMETER.

First.—The clamp screw on the shaft of the declination circle must not be used to set the declination circle at any hour angle except in the plane of the meridian circle at twelve hours when examining the adjustment of the instrument. When observing, this clamp must invariably be kept loose.

Second.—To change the altitude of the telescope the movement of the circles in azimuth, altitude and hour angle simultaneously must be done by moving the clamp block of the azimuth vernier in azimuth, except when the declination vernier is set near the pole, as is the case in observations of Polaris. In this case turn the declination circle and see that the azimuth clamp is loose.

Third.—The azimuth clamp and hour angle clamp on the shafts of the declination circle should be kept loose when changing the latitude or the elevation of the pole of the solarometer.

Fourth.—When not observing, the instrument should always be kept covered by its chamois skin cover to prevent dust, etc., from getting in on the bearings.

Fifth.—The float must not be used under any circumstances as a receptacle for any implements, pencils, knives, screw-drivers or adjusting bars, shades, etc.

Sixth.—The instrument may be cleaned by using a soft camel's-hair brush and piece of chamois skin. The instrument must be kept carefully dry and clean, but no vigorous rubbing to remove rust or oxidization on the surfaces of the circles should be attempted.

Seventh.—In case it should be necessary to dismount the instrument trom the float, the set screw at the bottom, by which it is screwed to the column on the float, must be carefully unscrewed, and the instrument raised by grasping it under the azimuth circle and carefully twisting it slightly while raising it vertically. Before dismounting, the latitude should be set at zero, the declination at zero, and the hour angle in the plane of the meridian circle. The upper circles will then all be vertical, and all the clamp screws should be set taut.

To put it in its transporting box, the instrument should be lifted by grasping with both hands under the two hemispherical arms *A* and *B*. It should be lowered in the box vertically, holding it with both hands and fitting it on to the spindle in the bottom of the box. After the box is packed with the wooden side blocks, the space around the instrument should be filled with wads or bunches of ordinary newspapers. Excelsior and similar material is not suitable, as small particles are liable to get in the shaft bearings. Bunches of soft newspapers make the best packing in the box for transportation by rail.

The importance of a constant available means of determining the compass error on board the modern steel vessels cannot be too strongly emphasized. Experience shows that no compensation of the compasses for the magnetism of the ship, nor any determination of magnetic effect upon the compass, will hold good for any length of time, or for great changes of position. The most constant observations are necessary in order that any confidence can be reposed in the compass, and even then its indications must be regarded with suspicion.

The compass error is obtained at present by time azimuth of the sun, observed by the alidade on the standard compass. This compass is now (in most approved patterns) a liquid compass in a bowl on gimbals. The alidade is fitted with sight vanes and a prism in which the observer is with difficulty obliged to find the sun, and then note the instant with his watch or chronometer. The observation is made in connection with a sextant to find the local time, since to find the sun's true bearing it is necessary to know the local time or the sun's hour angle.

The same results are obtained by such observations of the moon or stars, but in order to ascertain the true bearing of the moon or star observed, it is necessary to know that body's hour angle. This hour angle can, however, only be ascertained by elaborate calculation from a sextant altitude of the heavenly body. Sextant altitudes at night are, as has been stated, impracticable, and consequently at present it is only during sunshining daylight that compass error can be ascertained.

The solarometer thus incidentally accomplishes what is sought to be done by both the sextant and alidade, with the advantage of being available at night or in foggy weather, and obviating the necessity of any elaborate calculation; and besides this has the great additional advantage that whatever may be the result indicated by the solarometer, the observer can always know positively if his observations and results are right or not.

The inventor takes this opportunity to express his grateful appreciation of the assistance of brother officers and others in developing and perfecting this instrument.

Mr. G. W. Gail, of Baltimore, Md., generously promoted the enterprise by financial aid. The U. S. Lighthouse Board gave opportunities to test the original design on the steamer Violet. Mr. Malster, the builder of the cruiser Montgomery, further tested it on her trial trips. The director of the North German Lloyd Steamship Company gave facilities for sea trials on two transatlantic voyages in the S. S. Weimar. The Maritime Association of New York allowed the free use of the Maritime Exchange for an exhibition and lectures on the solarometer to the maritime community of New York for a period of two weeks. The American Line of U. S. mail steamers gave free passage to guarantee officers to try the solarometer on two voyages. The Cunard Steamship Company and the French Compagnie Generale Transatlantique have ordered solarometers on trial. The United States Navy Department has encouraged its development throughout, and put one on board the cruiser San Francisco.

This gratifying experience demonstrates the interest and general desire for the success of an instrument which can do what is claimed for the solarometer.

A thorough discussion and critical examination of the details of the solarometer and its appurtenances is earnestly invited in order that any imperfections may be revealed, and a perfect modern navigating instrument be evolved.

DISCUSSION.

The CHAIRMAN :—I have listened with great interest and pleasure to the description of the solarometer by its inventor, Lieutenant Beehler. This beautiful instrument which he exhibits to us represents, as I know, his patient labor for many years, and I desire to extend to him my congratulations on his success. Any plan or device to aid the navigator touches us very nearly, and we must regard it as of the highest importance. Although the solarometer is still in an experimental stage, the favorable reports of its practical working give promise of its future usefulness. The point of superiority in the instrument which especially strikes me is that it enables the navigator to ascertain the ship's position by observations of a heavenly body when the horizon cannot be seen. This is done by measuring from the zenith which is determined by the instrument. This property of the solarometer gives it a wider field than the sextant, and makes it available in cases when the horizon is obscured and the sun is shining overhead. I should think it would be especially valuable on many occasions when vessels are approaching our coast in foggy weather, for at such times the sun often shines out for a few minutes although the horizon does not clear. It also increases the accuracy and value of night observations, which are usually uncertain on account of the badly defined horizon.

I am doubtful about the extreme accuracy which is claimed in the results of the observations with the solarometer, but even if it only enables the navigator to determine his position by astronomical observation within a few miles, when otherwise his only guide would be the dead reckoning, it will afford him most material aid in these times when the magnificent ships already afloat frequently run more than five hundred miles a day.

The fact that with the solarometer on board the American Line S. S. New York when she was proceeding at high speed, the instrument was unreliable on account of the vibrations, does not seem to me to be a serious objection. If it is important to determine a ship's position accurately, she can always be slowed down or stopped long enough to take an observation, and the result will probably be a saving of coal and time as well as a greater degree of safety.

If the solarometer proves to be a navigating instrument of practical value, with which a ship's position can be determined by astronomical observations with reasonable accuracy, when without its aid this could not be done, the inventor can justly feel that he has added greatly to the security of life and property on the ocean, and he will deserve the thank of all seafarers. I believe that a careful trial of the instrument under the conditions of actual service will prove its worth.

Commander WM. BAINBRIDGE-HOFF, U. S. N.:—There are now several refinements in the arts, applicable to ships and navigation, which permit such an instrument as is the solarometer to become of great value. In fact Mr. Beehler has gone a long way towards supplying a necessity which the increasing speed in ships demands.

The passing out of sails in vessels on the great trunk routes of the sea, the solving of the problem of steadiness of platform, and the ability to steer to within small angles by means of steam make the use of the solarometer possible. Now there are no sails or spars to interfere with an observer's vision. Great steadiness of platform is scientifically procured through our present knowledge of the value of the distribution of weights in ships, while mechanical helm appliances, together with the inertia of large ship-masses, make steering much more accurate than formerly.

In the last thirty years the speed at sea of steam vessels has been doubled. In the next thirty years, this speed may be doubled or trebled. If this proves so, the voyager of 1925 may see a speed of a mile a minute at sea. Again, we find the 2000-ton ship of 1855 has become has become the 15,000-ton ship of 1895; will it not become in the year we have indicated, a vessel of at least 75,000 tons, and cost perhaps in the unnumbered millions of dollars, and hold a countless number of souls? If a ship of this size and speed becomes the packet of the future, it becomes then necessary to know *hourly* where the ship is, and when you are without a horizon for more than a third of the time of her run of three days through fog, haze or mist, and for half the time certainly through the phenomena of night, it makes such an instrument as the solarometer of priceless value.

In these days there will be carried an *astronomer* who, like a pilot, will be ever on the watch, while a "ticker" on the bridge or in the captain's room will keep the commander at all times advised of the ship's position.

Commander F. A. COOK, U. S. N:—It would be presumptuous for me to attempt to criticise, after a merely cursory examination, an instrument which has been perfected after years of patient and intelligent study and labor. I do not intend to do so, nor can I see wherein it can be criticised from my present knowledge of it.

The solarometer is a success, and has been so proven from experiment and use at sea. It is built upon a simple and plain theory. It is an astronomical triangle mounted upon a pedestal whose base is in the plane of the horizon, and its practical use depends upon its ability to maintain a constant level when mounted on the deck of a vessel at sea. It is in this ability that the ingenuity and patience of the designer is shown.

In clear weather the work of the navigator is truly "plain sailing." It is when the horizon is obscured that his anxiety begins and constantly increases as he approaches the land. Who that has navigated, but has often experienced the provoking and perplexing condition of a clear sky overhead, but an obscure and unreliable horizon? Just such conditions more often confront one in the vicinity of land. The solarometer meets these conditions perfectly, gives the position and corrects the compass. It is of inestimable value, and ought to be found upon all ocean craft. Unfamiliarity with its use should be no argument against it. The designer frankly admits that in extreme cases of vibration in high powered steamers, and in heavy seas the solarometer cannot keep its level. Under these conditions, if it did, it is quite certain most observers would not. The correct thing to do under such circumstances would be to stop for the observation, —a small concession indeed to make for so important a result.

I sincerely trust the inventor may receive his just reward by finding his instrument universally adopted and in successful use.

Commander A. D. BROWN, U. S. N.—The mechanical solution (*at sea*) of the astronomical triangle has long been greatly desired by the navigator. Numerous instruments for the purpose have been devised, but all have failed owing to the fact that the plane of the horizon could not be determined by them with a sufficient degree of accuracy. In the solarometer, as described by Lieutenant Beehler, this difficulty appears to have been entirely overcome. If the constant level of the base of this instrument can be preserved, as appears to be abundantly proven by the method of manufacture and the actual use of the machine, no further argument for its adoption would seem to be necessary. In these days of ships which are themselves huge floating magnets, the means of frequently and accurately determining the compass error has become an absolute necessity. This is unquestionably afforded by the solarometer, and its adaptation to stellar observations is a feature which should greatly commend it, as with its use it will be no longer necessary to go blindly along at high speed for ten or twelve hours every day without any means of ascertaining the true course and distance.

The navigators of the world are indebted to various officers of the U. S. Navy for many improvements in the exercise of their art, but it would appear to have been reserved for Lieutenant Beehler to devise an instrument which will render assurance doubly sure, will make the navigation of a ship a pleasure rather than a task, and will remove an immense weight from the commanding and navigating officers of all vessels that have what we may well call "the automatic position and compass error finder," as a portion of their equipment.

Lieut.-Commander J. G. EATON, U. S. N.:—Although I have studied the solarometer with a view to offering some technical criticisms, I shall confine the few remarks I offer more to the practical side of the question, and content myself with stating that I fully believe that the defects which now exist are entirely due to the difficulties of construction, and not to faults in the theory.

Every navigator, vexed and perplexed by dim horizons, must have prayed for some point *d'appui* more reliable than the shifting line where sky and waters meet. A visible zenith would prove a blessing to every sea observer who seeks to establish his position. Lieutenant Beehler has originated and developed in his solarometer an instrument which practically confers on the observer a horizon that neither land nor fog can obscure.

I have not seen the solarometer at work afloat, but I can speak of its accuracy on shore, and the results laid before you in this paper will show you that the instrument is reliable, and that by its use we may eliminate the unreliable true horizon, and gives in place thereof, an always determinable circle of reference.

The mechanical portions of the instrument are so well adjusted that even the preliminary trials have shown great accuracy. The results on the sea show that the results may be relied upon within the limits of the usual errors of observation. The correction of the errors due to refraction presents the greatest difficulty. The true path of a heavenly body, and this is the only path for which the co-ordinated circles can be used, must always differ from the apparent paths due to refraction. The empirical method of correction, that of using the squares of the reticule, appears crude and unsatisfactory for refined observations. No better method presents itself, but the use of the one advocated must detract from the value of the observation.

Unquestionably, as the solarometer becomes generally used, slight changes in sections, conducing to greater steadiness, with consequent facility of observation will suggest themselves. The instrument is still, though developed, in its experimental stage, and faults due to design and want of poise will be corrected as they are recognized.

As it stands to-day, the solarometer marks a wide departure from our present methods, and its results, creditable as they are, fail to show its great superiority over horizon sextant observations.

Lieutenant Beehler has invented, and I may add, well nigh perfected, an instrument which bids fair to revolutionize the accustomed methods of ascertaining a ship's position at sea. I do not regard it as essential, or indeed wholly practicable, to determine the latitude and longitude by single observations. But as to the essential points, the solarometer can do all that the sextant can, and besides, can be accurately used where the sextant, deprived of the horizon, is useless.

The great value of such an instrument to a man-of-war will be appreciated. The importance of correctly establishing the ship's position at any time, day or night, has greatly increased with the speeds now in use. Cases will readily occur to naval officers, where swift descents upon an enemy's coast or fleet must depend for their success, upon the correctness of the departure. Any instrument of navigation which eliminates the uncertainties of the day horizon, and gives us one at night which can be relied upon, will prove of inestimable value.

I fully believe that the solarometer does, or will do these very things.

Lieut-Commander RICHARD WAINWRIGHT, U. S. N.:—The advantages of the solarometer as may be gathered from Lieutenant Beehler's paper, are the constant level or base, which provides a means of taking observations independently of the visibility of the sea horizon, and the use of a mechanical means of solving the problems in place of solving them mathematically.

Many attempts have been made to solve the problem of ascertaining the latitude and longitude at sea when the horizon was obscured or invisible. Several attachments to the sextant have been patented, but none have proved very successful when brought into practice, although correct in theory. If Mr. Beehler has solved the problem and his instrument is capable of being handled practically, as well as being theoretically correct, his invention will be of great value to the mariner. The difficulty heretofore has been to handle a necessarily delicate instrument with sufficient skill to produce good results under the different conditions prevailing at sea. Some of us may remember that Professor Chauvenet held that there was no reason why as exact observations should not be taken with a sea horizon as with an artificial one. He stuck to his proposition until on a practice cruise, when he undertook to take sextant observations while the vessel in which he was cruising was under the influence of a choppy sea. Then he expressed doubts as to the possibility of ever getting reliable observations at sea.

Mr. Beehler says: "The solarometer obviates elaborate logarithmic calculations and combines in itself a pelorus; so that it furnishes a complete solution of the entire problem to ascertain the ship's position and compass error in the space of time ordinarily required to observe the altitude by the sextant, and take its bearing with a pelorus." This sentence is misleading, as, in the first place, there are no elaborate calculations necessary in order to ascertain the ship's position from sextant observations; the calculations are simple and occupy but little time when the navigator is in practice. Again, the nature of the problem is such that the instrument cannot obtain, under ordinary circumstances, good longitude results and good latitude results from the same heavenly body at the same time. Either the body will be nearer the prime vertical and the hour angle will be good while the latitude will be bad, or it will be nearer the meridian, when the opposite will be the case. If we examine the method of taking observations it will be found that when the latitude is unknown it is necessary to take four observations before the correct hour angle is ascertained, and then, in spite of the inventor's claim, the latitude must be in doubt. To take the observations and compute the results, it is necessary to take out the same quantities from the nautical almanac and from Bowditch as when the sextant is used, except the dip, semidiameter and four logs. In addition, it is necessary to make a small calculation from the readings of the compass rose to obtain the true course. When four observations are required, I believe it would be as well, if not better, to work a Sumner with the instrument.

The necessity of allowing for refraction is another difficulty with this instrument. It is evident that it would require a very highly skilled observer to allow for the effect of refraction by the position of the heavenly body in the telescope. Except when the body is both high in altitude and near the prime vertical, when the effect of refraction can be ignored; tables must be consulted, and the hour angle and azimuth corrected. Unless high in altitude and near the prime vertical, only stars that have a declination within the limits of the sun can be used, or very large tables must be computed. This refraction is a very bothering quantity for the inventor, for it varies with different states of the atmosphere and during low-lying fogs the quantity given in the table may be far from correct at a time when the solarometer should be most needed.

The inventor further says: "And besides, this has the great additional advantage that, whatever may be the result indicated by the solarometer, the observer can always know positively if his observations and results are right or not." This is incorrect. By use of the azimuth tables taking the hour angle observed, and the latitude and declination used, if the azimuth found in the tables corresponds with the one observed, the instrument may be said to be in adjustment. Should the observation be taken improperly or wrong quantities used, the error must be serious to be detected by the tables. The body might be observed slightly out of the center of the telescope, and if it were near the prime vertical, a latitude far from correct recorded without an apparent change in azimuth. The fact is with this instrument as with the sextant, the navigator may be sure that his results are in error. What he desires to know is within what limits he can rely upon his results. The main question to be determined for the solarometer is, Within what limits can it be relied upon, at night, or in the daytime, when the horizon is obscured and the sextant of no use? If the probable error is sufficiently small, the instrument is of great value.

I believe the claims made by the inventor are too large and that they are likely to retard the progress of the instrument in its way towards general adoption; for, when unexpected difficulties are encountered with a new instrument, it is liable to fall into disrepute. The value of the solarometer does not depend, fortunately, upon its doing away with elaborate calculations, producing absolutely accurate results or accomplishing impossible tasks. What must be known is, Can the instrument be used in ordinary practice, in spite of the vibrations, rolling, pitching and yawing of the ship? Will the many adjustments remain correct for a reasonable time within reasonable limits under ordinary conditions? These questions should be answered shortly with three instruments afloat, and, if answered favorably, the solarometer must be adopted by all vessels of sufficient size to afford a proper location. If the instrument prove reliable, it must serve to save enough coal to more than compensate for its cost in a few trips; and its value to commerce is beyond estimation when the additional security to life and property is brought in consideration.

Mr. JOHN MARTIN :—Having made six transatlantic voyages in charge of a solarometer on board of the U. S. M. S. New York, my experience has demonstrated the practical success of this instrument, under all conditions, except when excessive vibrations of the ship disturbed the float to such an extent, that it was almost impossible to judge when the body observed was in the axis of the telescope.

The solarometer was mounted in the New York on the hurricane deck directly over the thrust bearings of the engines, and in that place the vibrations of the engines were transmitted directly to the deck upon which the solorometer was secured.

On the first round trip voyage from New York to Southampton and return, December 12, to December 29, there was so little clear sky that there was no opportunity to test the instrument. I myself had had but a few hours experience in observing with the instrument before I went on this voyage, and was not sufficiently familiar with the manipulation of the instrument to get star sights.

On three days at sea I got snap shots of the sun, and my results agreed to within six miles of those observed by the sextant; while in port at Southampton, and subsequently at New York, on January 1, I obtained perfectly accurate results by observations with the solarometer.

On the second round trip voyage, from January 2 to the 19th, experienced some clear weather on the eastward voyage, and obtained some good results, but in the long following seas, the engines *raced* to such an extent, that the excessive vibration often made it impossible to determine positively when the sun was in the axis of the telescope; many of the observations were found to be erroneous, and were discarded, as they did not show agreement with determinations by the sextant. Such results as agreed with the sextant closely, also agreed in the comparison of the computed and instrumental values of hour angle, latitude, declination and azimuth.

The steamer New York went to Newport News, Va., to be docked on January 20, and on this trip the ball and socket joint of the float was removed, and thereby a great deal of the effect of excessive vibration was compensated. Under ordinary conditions, the removal of this bolt prevented much of the vibration of the ship from being communicated to the float, and I thought the only difficulty had been overcome.

I sailed again for Southampton on February 13, and obtained a series of observations, in which throughout the voyage I was enabled to ascertain the ship's position and compass error, except at times when the vibrations were such that the results were indeterminate.

Captain Jamison, commanding the New York, was much interested in the solarometer, but during these winter voyages the sun was so rarely visible, and so low in the bank of clouds and horizon, that he had not sufficient time or opportunity to become so familiar with the instrument, that he could rely on its indications: though by carefully comparing the readings of the solarometer with the computed value of azimuth in the book of tables, he has positive evidence of the correctness of results.

The method of allowing for refraction by observing the body in the telescope as much below its axis as refraction elevated the body above its true position, was practiced in the first two voyages, but on the last voyage, much better results were obtained by accurately allowing for the refraction and observing the body directly in the axis of the telescope.

Captain Jamison expects to use the solarometer through the spring and summer, when he will have more time to familiarize himself with its workings, and its value will become apparent in foggy weather during the coming spring and summer weather.

The position of the solarometer on board the New York, is unfavorable because that part of the ship is subjected to greater vibrations than any other. A much better position would be near the pilot house, but there, other reasons prevented its being mounted, and in order to get it on board at all, it was necessary to yield and place it where it was most convenient and least in the way.

Lieutenant G. L. DYER, U. S. N.:—Mr. Chairman, I would like to hear some account of the inventor's own experience with the solarometer at sea.

Lieutenant BEEHLER, U. S. N.:—I made two round trips, transatlantic voyages, in the North German Lloyd steamer Weimar, from Baltimore to Bremen, in March and August, last year.

On the voyages I had solarometers which were subsequently greatly improved, but though imperfect instruments, I was able at times to obtain good results which demonstrated the practicability of the instrument.

In these instruments, by setting the arcs in positions corresponding to the computed values of the four quantities of declination, latitude, hour angle and azimuth, and waiting for the sun or star to be visible in the axis of the telescope, I could get accurate and reliable results. The defects of the instrument were removed in the subsequent design, but the experience demonstrated that the rolling and pitching motion of the ship was fully compensated by the arrangement of the float in the bowls.

A Hicks clinometer was fixed near the instrument, and observations were taken, and accurate results obtained, when the ship was rolled 20 degrees each way. At one time I tried to get observations when the ship was rolling deeply, 40 degrees each way, but the heel was so great that it was impossible for me to reach up so as to have my eye at the eye piece of the telescope. It would have been necessary for me to have been about 7 feet tall to reach over, but for all that, I could see the shadow of the sun shining in the field of the telescope, even when rolling 40 degrees each way. At this time, the Weimar was flying light, with very little cargo, and in a heavy sea. The instrument was mounted on the hurricane deck, about 42 feet above the water-line, and the rolling and pitching motions were fully compensated.

In reply to the criticism of Lieutenant-Commander Wainwright, in regard to the refraction, I admit that there is, and has been, considerable trouble with refraction, but no more, nor in fact as much, as with a sextant.

In developing the instrument, the question of compensating or correcting for refraction has been a serious one. I find that it is best to correct the hour angle by a correction from tables corresponding to the hour angle, polar distance and latitude, or altitude; these tables are not as long as at first seems probable, and can be readily applied. The accuracy of the table of refraction has been questioned, but the error is small. I was under the impression that the amount of moisture in the atmosphere would have a serious effect on its refraction, but I have in a letter from Professor Harkness the statement that in the most refined observations of astronomers the moisture of the atmosphere is neglected, the temperature and pressure determining its density and refractive power.

The criticism of the proof claimed by the agreement between the computed and instrumental values of hour angle, declination, latitude and azimuth, seems to overlook the fact that as with all other instruments of precision, accurate results can only be obtained by careful and precise work. If the body observed is seen exactly in the axis of the telescope, and if the graduated circles are accurately read, it follows as an axiom that if the computed and instrumental values agree, the result is correct, and the observer has proof of the accuracy of his observation. This feature has been used to obtain results with an imperfect instrument, and the practice has demonstrated the correctness of the claim.

In conclusion, unless there is any other point which I may explain, I desire to express my sincere thanks for the kind expressions of approval, and good wishes of those who have discussed the paper. In this connection, I feel deeply sensible of the favorable consideration I have met with on every hand. I have often heard it stated that the Hon. Navy Department does not encourage inventors. My experience has been quite the reverse, for I have had no reasonable request refused, and have been encouraged in every way. Your kind attention is another evidence of this feeling, and I thank you all sincerely for this most flattering reception.

The lecturer exhibited and explained the various forms of the instrument, beginning with the early imperfect ones and ending with that at present set up for trial and use in the Naval Academy grounds. After tendering a vote of thanks to the lecturer for a very entertaining and instructive lecture, the meeting adjourned.

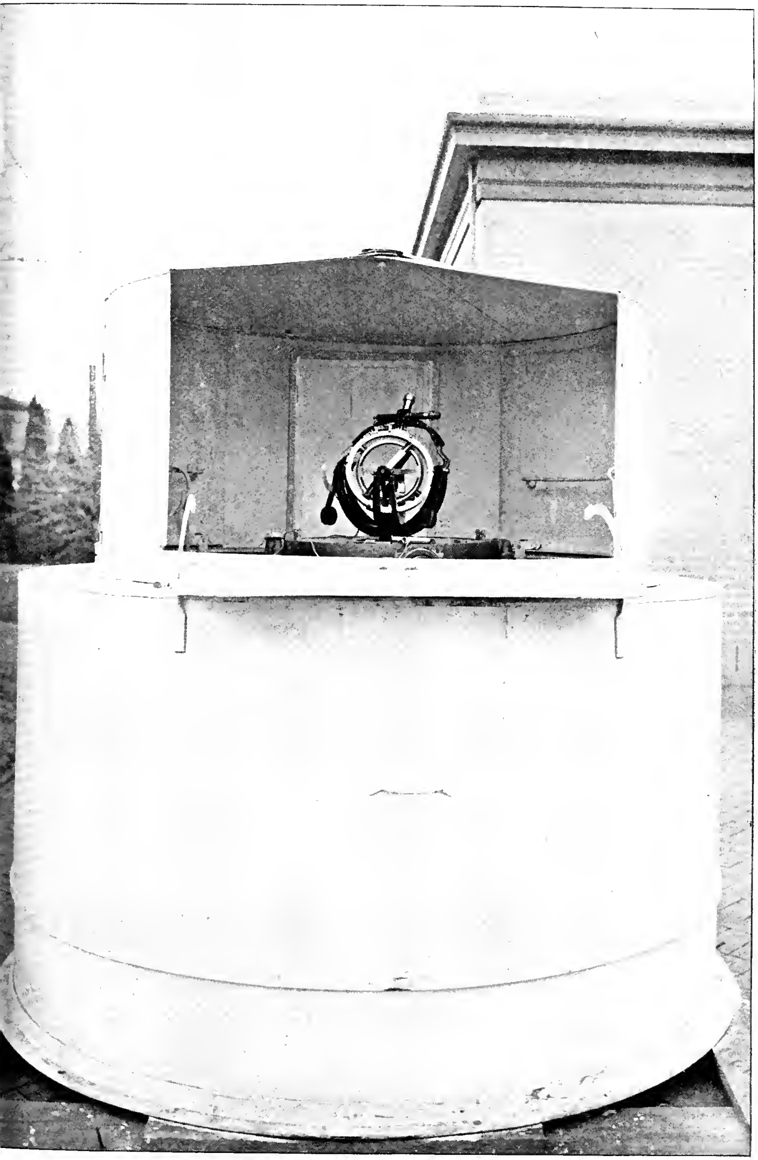


FIG. 6.—VIEW OF SOLAROMETER IN ITS OBSERVATORY AT U. S. NAVAL ACADEMY.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

ELASTIC STRENGTH OF GUNS.

By Lieutenant J. H. Glennon, U. S. Navy.

Much has been written on the subject of elastic strength of guns in the endeavor to make the subject perfectly clear, with the result that many books on the subject are filled with formulas. Lately the subject has been illustrated with geometrical diagrams quite as complicated as the formulas themselves, so that experts who examine them will probably find themselves wondering if, after all, they know anything about the question. It is thought that the subject may be presented in an elementary way without the use of many formulas, illustrating by numerical examples.

The basisof the modern theory is that within the elastic limit, that is, the limit at which if the load is removed a metal will assume its original dimensions, the strain (stretch or shortening per unit length) is proportional to the stress (or load per unit area). This is probably only approximately true for some metals. For example, some mild steel stretches less just within the elastic limit for a positive increment of stress than it does lower down. It seems to save up, so to speak, for a greatly disproportionate stretch just above the elastic limit; after this excessive stretch, the amount of strain for an increment of stress becomes nearly as small as below the elastic limit and then increases gradually till the ultimate load is obtained, the specimen breaking at a load somewhat lower than the highest point reached.

The highest stress obtained is the tensile strength and the stress that strains a metal to its elastic limit is the elastic strength of the metal (for extension or compression, as the case may be). A distinction should be carefully observed between the elastic strength of a metal and the elastic strength of a gun built of the metal, the last being the pressure per square inch which, when applied to the gun internally, will permanently deform it by straining some portion of the metal beyond its elastic limit.

Following the ordinary custom, we will consider the strain within the elastic limit as proportional to the stress in the same direction, when this is the only stress applied. We will, moreover, only consider metals while acting inside their elastic limits, the various fundamental rules given applying only with this condition.

Within the elastic limit, then, if a thousand pound pull is given to a specimen of metal, and then a thousand more is added, the stretch for the second will be the same as for the first. This is equivalent to saying that the strain due to any stress is independent of prior stress. A second rule is that when a stress of tension (or compression) is exerted upon a metal, the strains in directions at right angles are $\frac{1}{3}$ of that in the line of the stress and are contractions (or extensions). The coefficient $\frac{1}{4}$ is sometimes used in place of $\frac{1}{3}$, but this latter is used almost exclusively by the Army and Navy ordnance bureau officers. If two or more stresses at right angles act upon a specimen, the total strains in each direction will be the algebraic sum of the strains in that direction, each component strain being independent of prior strain and each being readily calculated by the rule for the strains produced by a single stress.

The ratio of the stress to the strain caused by it in the same direction is called the modulus of elasticity of the metal and will be denoted by E.

It is necessary to use calculus only once in the subject of elastic strength of guns, namely, to get the fundamental formulas for tension and radial pressure.

The stresses acting upon a point in the thickness of a gun may be resolved in the three directions of the length, the thickness, and perpendicular to a radius of the gun and the length. Any point at rest is held by equal and opposite forces or otherwise it would move in the direction of the greater force. So that we may represent the radial pressure on any particle by two opposite and equal arrows pointed towards each other along a radius, and the circumferential tension at any point by two equal and opposite arrows pointed tangentially and away from each other. The longitudinal stress would likewise be represented by equal and opposite arrows in the direction of the length.

We will denote the radial stress by p, the circumferential or tangential stress by t and the longitudinal stress by q. Similarly, strains in the same directions will be denoted by $[p]$, $[t]$ and $[q.]$

If we denote the pressure inside of a closed cylinder by P_0, outside by P_1, the internal radius by R_0 and the outside by R_1, and suppose a plane surface passed through its axis, removing one half of the cylinder, it will be evident that the total tension of the cylinder at the points of junction with the plane must be $2(P_0R_0—P_1R_1)$ multiplied by the length of the cylinder, since this will be the total pressure on the flat surface tending to separate it from the half cylinder. But the presence of the flat surface will in nowise alter the forces causing stress in the cylindrical part, and this is evidently therefore the total tension throughout the two thicknesses of the original cylinder.

By dividing this quantity by the area of the section of the metal, we find the mean tension per unit area. A similar method of finding tension will apply to any cylindrical element, so that we readily find a differential expression and then, by integration, the law of radial pressures and tensions throughout the thickness. This is the occasion in the study of elastic strength of guns where we are compelled to use calculus. Such calculus as is necessary is however very simple, but we will not go into it here, and will consider the results only. They are for the varying radial pressure p at any radius r,

$$p=\frac{c_2}{r^2}-c_1, \qquad \ldots\ldots\ldots \qquad (1)$$

and for the circumferential tension t at the same point,

$$t=\frac{c_2}{r^2}+c_1. \qquad \ldots\ldots\ldots \qquad (2)$$

The three conditions necessary to the deduction of these equations (which are absolutely independent otherwise of the metal) are uniform elasticity (or constant modulus), uniform longitudinal stress, and uniform longitudinal strain throughout the thickness. In them, c_2 and c_1 are constants. The longitudinal tension q is, following Clavarino, equal to c_1, and according to Birnie, zero. Birnie's assumption will give lower elastic strength generally and therefore being safer, is taken here. It seems moreover to agree more nearly with the facts.

Summing up the strains in the three directions as before indicated, that is, algebraically, we find for the strain $[p]$ in the direction of the radius (due to p and t),

$$[p]=\frac{1}{E}\left(-p-\frac{t}{3}\right)=\frac{2}{3E}\left(c_1-\frac{2c_2}{r^2}\right), \quad . \quad . \quad . \quad (3)$$

for the strain $[t]$ tangentially or circumferentially (due to p and t),

$$[t]=\frac{1}{E}\left(t+\frac{p}{3}\right)=\frac{2}{3E}\left(c_1+\frac{2c_2}{r^2}\right), \quad . \quad . \quad . \quad (4)$$

and for the longitudinal strain,

$$[q]=\frac{1}{3E}(p-t)=-\frac{2c_1}{3E}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

None of the resultant strains of the metal must ever exceed the elastic limit determined by dividing the elastic strength by the modulus of elasticity, or else the gun will be permanently deformed. These five equations are all that are necessary in the subject, if judiciously handled.

Example :—The internal and external radii of a tube are 3″ and 4″, the elastic strength of the metal for tension or compression (the two are usually taken equal for gun steel) is 60,000 lbs., and the modulus of elasticity (that for steel) 30,000,000. What is the elastic strength?

$$\text{The Elastic limit is } \frac{60{,}000}{30{,}000{,}000}=.002''.$$

The strain used will always be the greatest numerically since the elastic limits for extension and compression are assumed equal numerically.

Unless c_1 is different in sign from c_2, $[t]$ will always (see (3) and (4)), be numerically greater than $[p]$; $[t]$ or $[p]$, one of them, will be greater than $[q]$ numerically. The strain used will always be greatest numerically when r is smallest; that is, at the inner surface (see (3) and (4)).

We will first put the elastic limit equal to $[t]$, the strain circumferentially at the inner surface of the tube.

We have therefore, by (4),

$$.002=\frac{2}{90{,}000{,}000}\left(c_1+\frac{2c_2}{9}\right). \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The external pressure is the atmospheric, which we will call 0, and the greatest internal pressure that the tube can stand will be its elastic strength.

We have, remembering that the external pressure is 0, $p = 0$ when $r = 4$. Hence, by (1),

$$0 = \frac{c_2}{16} - c_1, \text{ or } c_2 = 16c_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Substituting in (6) we find, $c_2 = 316,096$, and $c_1 = 19,756$; and finally, from (1), placing $r = 3$ the internal radius, we have $p = 15,366$ lbs., which is the elastic strength of the tube (as $[t]$ is the proper strain to use, being greater numerically than $[p]$ because c_1 and c_2 are positive).

To summarize the operation performed, we have assumed the internal strain and external pressure and found the corresponding internal radial stress or pressure.

Now suppose this tube is shrunk on another of radii 2″ and 3″ (about), the condition being that each tube shall stretch internally to its elastic limit when the maximum pressure acts. The internal pressure of the outside tube will be the external pressure of the inside tube.

Suppose the elastic strength of the metal for tension or compression of the inside tube to be 60,000. Then $\frac{60,000}{30,000,000} = .002$ is the limit of allowable strain. We place then, by (4),

$$.002 = \frac{2}{90,000,000}\left(c_1 + \frac{2c_2}{4}\right),$$

or,

$$180,000 = 2c_1 + c_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and, remembering that the pressure or $p = 15,366$ lbs. when $r = 3$, we have, by (1),

$$15,366 = \frac{c_2}{9} - c_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

From these two equations we determine $c_2 = 172,417$ and $c_1 = 3791$ for the inside tube, and then the internal pressure or elastic strength by (1), whence $p = \frac{c_2}{4} - c_1 = 39,313$ lbs. In this tube c_2 and c_1 are both positive and the $[t]$ strain (as we find by trial, solving for c_2 and c_1) is the one to use. If the elastic strengths for compression and extension are not the same numerically we may now try the values of c_2 and c_1 in (3), and see how $[p]$ compares numerically with $[t]$. If the ratio of $[p]$ to $[t]$ does not exceed the ratio of the elastic strength for compression to that for extension (and the order of work is based upon the fact that it generally does not), we have the correct elastic strength. Otherwise the elastic strength of the gun is limited by the compression of the inner points of the thickness in a radial direction, and we place $[p]$ equal to the elastic limit of compression (with its proper negative sign) and proceed as before.

If now there is a tube of 1″ inner radius inside, we take as its external pressure that last calculated and proceed as before. So that, given the dimensions of the various tubes of a built-up gun, we can readily calculate how much pressure the gun can stand. Taking the elastic strength of the metal as 60,000 lbs. for extension and compression as before, we have, by (4),

$$.002 = \frac{2}{90,000,000}\left(c_1 + 2c_2\right), \quad . \quad . \quad . \quad . \quad (10)$$

and by (1),

$$39,313 = \frac{c_2}{4} - c_1. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

From these we find $c_2 = 57,472$ and $c_1 = -24,945$. Because of the difference in signs of c_1 and c_2, $[p]$ is greater than $[t]$, numerically, and these values are not the ones to use. We now place $[p] = -.002$ in (4), giving

$$-.002 = \frac{2}{90,000,000}(c_1 - 2c_2), \quad . \quad . \quad . \quad . \quad (12)$$

and from this and (11) we find $c_2 = 28,964$, and $c_1 = -32,072$ as the correct values of c_2 and c_1 for the inner tube. The elastic strength by (1) is $p = 28,964 + 32,072 = 61,036$ lbs.

SHRINKAGE.

The shrinkage is equal to the algebraic sum of the compression of the external diameter of the inner tube, and the extension of the inner diameter of the outer tube, the dimensions of only the two tubes in question at the time being considered. We consider the two tubes in question as they were before being put together, and can then work to any condition in which they may be after being joined. Another way to state the same thing is that the shrinkage is equal to the algebraic difference of the extensions of these same diameters in working from the first to any final condition. How much is the inner tube of the above gun compressed externally by a pressure of 61,036 lbs. on the inside and 39,313 lbs. outside? The diameter would be compressed $\frac{1}{3.1416}$ times as much as the circumference, or by the product of the diameter by the strain [t] per unit length of the circumference, taken with a minus sign (a positive compression is a negative strain).

The 4″ diameter of the inside tube will be compressed by (see (4))

$$-4\,[t] = -\frac{8}{90,000,000}\left(c_1 + \frac{2c_2}{4}\right) =$$

$$-\frac{8}{90,000,000}\left(-32,072 + \frac{28,964}{2}\right) = .00,156.$$

What is the extension of the second tube under the same circumstances, namely that caused by 39,313 lbs., acting inside at radius 2″ and 15,366 lbs. outside at 3″?

We substitute the value of c_1 and c_2 in (4), multiplying by the diameter and find the extension of the inside diameter to be (see (4)),

$$4\,[t] = \frac{8}{90,000,000}\left(3791 + \frac{172,417}{2}\right) = .008\,;$$

and the shrinkage is the first plus the second, or .00,956″. (The extension of the inner diameter of this tube need not be calculated in this way, since each unit of the inner circumference of the tube is strained to its elastic limit of extension).

In shrinking on the outside tube we shrink upon both the inner tubes. The shrinkage is the same as it would be on a simple tube of the same dimensions that could stand the same pressures inside and out. The question may be put: What would be the compression of the external diameter of a tube of 1″ inner radius, 3″ outer, due to a pressure inside of 61,036 lbs., and outside of 15,366 lbs.? What would be the extension of the inner diameter of the outside tube, 3″ inner and 4″ outer radius, due to an internal pressure of 15,366 lbs., and an external pressure of 0 lbs.? Both of these would be found as before, it being noted that a new c_2 and c_1 would have to be calculated for the entire inner tube under the given conditions. The sum is the shrinkage.

The stretch depends on the dimensions and modulus of elasticity. Any tube will strain in exactly the same way as a simple tube of the same dimensions and modulus of elasticity. That is, we follow our original statement that strains due to any cause are independent of other strains already existing. In a simple tube we placed $[t]$ equal to the limit of strain to get our elastic strength. In no gun can we do more than place it equal to the numerical sum of the elastic limits for compression and extension. This represents the greatest scope through which a metal can work and more cannot be realized in any gun either through casting on the Rodman process, wire-winding or by other devices. The greatest strength that any gun can have is dependent on the amount of strain possible with the layer of metal next the bore. We work between elastic limits, and the best metal is reliable, homogeneous steel of the greatest difference between the two. Compressive strength is just as necessary as tensile strength. Difference between the two limits is what is required. In the Brown wire-wound gun, the inner layer has practically no elastic strength for tension. The excessive compressive strength of the staves, however, gives the gun a high strength, nearly as high in fact as that of another wire-wound gun with continuous metal next the bore, and having the same algebraic difference between the two elastic strengths.

The amount of elastic strain of which the metal next the bore is capable, is evidently $\frac{\theta+\rho}{E}$, where θ and ρ are the elastic strengths for extension and compression (numerically), and E the modulus of elasticity; and the greatest possible strength of a compound gun will be the internal pressure necessary to strain a simple tube of the same dimensions and modulus through this same amount. That is, when $[t]=\frac{\theta+\rho}{E}=\frac{2}{3E}\left(c_1+\frac{2c_2}{R_0^2}\right)$ where R_0 is the inside radius, and $p=O=\frac{c_2}{R_1^2}-c_1$ where p and R_1 are the external pressure and radius respectively, $p = \frac{c_2}{R_0} - c_1$ will give the greatest elastic strength possible with the gun of the given dimensions and modulus.

From these it will follow that a wire-wound gun will be weaker than another built-up gun of larger dimensions, but the same modulus, in which the same compression before firing of the same interior tube is accomplished. The greatest elastic strength possible with a gun of the same metal and same inside and outside dimensions as the one we have been using, calculated in this way, would be over 80,000 lbs.

Apropos of wire drawing it may be said that if a specimen of steel is placed in the testing machine and permanently strained by say 90,000 lbs. pull per square inch, and is then taken out of the machine and retested as a metal, it will now show over 90,000 lbs. elastic strength, and from its smaller original area in this last case, greater ultimate strength than before. Does this cold drawing increase its elastic strength for compression, or even keep it the same, and is the metal any better for gun purposes than it was before? If so, would it not be well to fire heavy proof charges, as in the old converted guns, and then finish bore and rifle the gun?

The effect of successive shrinkages is to continually compress the metal next the bore.

Now, in calculating the strength of the gun we found the pressures at contact surfaces when the maximum firing pressure (the elastic strength of the gun) acted on the inside, and o on the outside of the gun. If we take a simple tube of the same dimensions and modulus, and suppose the same firing pressure to act, the stresses and strains at the same radii will represent the changes in the stresses and strains of the compound tube, and by subtracting these from the final stresses and strains of the built-up gun, we obtain those in the gun when no pressure is acting. That is, in (1) we place p equal to the elastic strength of the gun, and r equal to the inner radius. Next we place $p = o$ and r equal to the outer radius; we thus have two equations and two unknown quantities, c_1 and c_2. Solve for these, and plot the curve shown by (1). The ordinates are the changes in radial pressure in the compound tube due to firing with a pressure equal to the elastic strength of the gun, and from these and the calculated pressures at the contact surfaces in the gun when in action, we find the pressures at rest by subtraction.

The pressure at rest on the outside of the inner tube is what causes the compression of the bore. In (1) we place p equal to this pressure at rest, and r equal to the outside radius of the inner tube. Next we place $p=0$ and r equal to the radius of the bore. From these two equations we find c_1 and c_2 as before. We substitute these in (4), making r equal to the radius of the bore, and the result is the strain (per unit) of the circumference, which is the same as the strain (per unit) of the radius, and by multiplying by the diameter (and taking the negative) we get its total shortening, or the total compression of the bore. The compression per unit should not exceed the elastic limit of compression. In the gun that we have arbitrarily assumed the increase in radial pressure at the contact surface of 2″ radius, caused by 61,036 lbs. inside and 0 pressure outside the gun, is 12,207 lbs. ($c_1 = 4069$ and $c_2 = 65,104$ for simple gun), and as the pressure during firing at this surface is 39,313 lbs., the pressure when the gun is at rest is $39,373 - 12,207 = 27,106$ lbs. Can the inside tube stand this pressure when the inside pressure is 0? We find under the given conditions that $c_2 = c_1$, that $27,106 = -\frac{3}{4}c_1$, and on the inside that $[t] = -.0024$, which is greater numerically than $-.002$, the elastic limit of compression. The tube would therefore be permanently deformed, and we cannot * build a gun of these dimensions and this metal so that in firing the interior of the second tube will be strained to its elastic limit. The shrinkage on the inner tube may be determined, however, to meet the condition that this is not deformed when the gun is at rest.

It should be noted that the pressure at rest outside the inner tube is due partly to the successive outside shrinkages. If, now, the compression per unit of the diameter of the bore is less than the elastic limit of compression, we may shrink on another hoop if desirable with such shrinkage as will bring the compression of the bore to this limit. Thus, in (4) we place $[t]$ equal to the strain (negative) required, and r equal to the inner radius. In (1) we place $p = 0$ and r equal to the inner radius of the gun. From these two equations we find c_1 and c_2, and substitute them in (1), making r the original outside radius of the gun (before putting on the hoop). The result is the pressure required between the original gun and the hoop.

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* All strains being within elastic limits.

We have now the pressure at the surface of contact, and we require the shrinkage.

In (1), we substitute this pressure for p and the radius of contact for r. Next we place $p = 0$, and r equal to the radius of the bore. Solve for c_1 and c_2 (they have already been found, however,) and substitute in (4), making r the radius of contact. The result is the strain, and taken with a negative sign is the compression (per unit) of the outer diameter of the inside portion. In (1) we substitute the pressure at the surface of contact for p, and the radius of contact for r. Next 0 for p and the external radius for r. Solve for c_1 and c_2. Substitute in (4), taking r the radius of the surface of contact, and the result is the extension per unit of the inner diameter of the hoop. Add this extension to the preceding compression and multiply by the diameter, and the result is the required shrinkage. Various other problems might be solved in the same way but will not be gone into here. Our endeavor has been to avoid the usual nomenclature of books on the elastic strength of guns, which is something appalling, by the use of equations that will keep what we are doing clearly before us. Certain minor operations are duplicated in the description, which would not really be necessary with actual numerical cases, and it is thought that this adds to the clearness. It may be remarked that the pressures at the surfaces of contact of a built-up gun when the gun is at rest may be used to find the shrinkages, in exactly the same way as shown in this note using the maximum firing pressure. In fact, the corresponding pressures at these surfaces under any given conditions * may be used.

If two adjacent cylinders in a built-up gun have the same elastic limit, the most advantageous intermediate radius will be a mean proportional between the other two radii. The proof of this will not be given here as it would unnecessarily complicate what is intended only as a brief summary of the subject. Other considerations frequently interfere with this. For example, the jacket of a modern gun is made of sufficient thickness to withstand the longitudinal pull between trunnions and breech block. If P_0 and R_0 are the elastic strength of the gun and the radius of the exposed

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* Attention is called to this by Captain J. P. Story, U. S. Artillery, in his Elastic Strength of Guns. It may be stated here that the notation used for strains is his also.

nose of the breech block respectively, θ the elastic strength of the metal and R_1 and R_2 the interior and exterior radii of the jacket, $\theta\pi(R_2^2 - R_1^2)$ should be equal to or greater than $P_o\pi R_o^2$, so that no unit area may be exposed to a lengthwise pull greater than the elastic strength of the metal.*

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* It may be necessary to consider the strains. Tangential stresses decrease and radial pressures increase the longitudinal strain, so that the longitudinal stress, as here used, should give fair results. If strains are considered, they should be determined originally on the condition that the longitudinal stress of the jacket is the one here used.

PROFESSIONAL NOTES.

LEAK ARRESTERS FOR SHIPS.

Experiments made by Mr. Colomès, a French inventor, with cellulose applied to holes in the hull, induced the French Government to adopt his device to be used on board its war vessels.

The apparatus for applying the cellulose to the hole is extremely simple. It is composed of a steel rod, threaded on a part of its length, at the end of which is pivoted an iron piece, which, when at right angles to the rod, has the appearance of a pickaxe, one of the arms of this cross piece being heavier than the other. This cross piece has fixed to it an oval piece of flat iron covered on both sides with thick felt. A small conical bag, filled with cellulose and having a hole through its center, can be slid on to the rod. Back of this bag is applied a large washer, which is held in place against the bag by a nut which is pushed down the rod to the threaded part, where it engages the screw. When a leak has been located any man can seize a leak stopper corresponding approximately in size to the width of the hole. Then holding it with the lighter end of the pick toward him, so that the pick and oval plate lie alongside the rod, he can introduce it into the hole. He can avoid the rush of the water by standing to one side. As soon as the pick has passed through the plating the heavier end descends and the pick places itself across the hole while the pressure of the outside water forces it against the side of the vessel and throws the pick arm across the opening, so, resting on the plating around the hole, it affords a point of support, while the felt covered plate reduces the leak very much and makes easier the next operation, which consists in slipping the bag of cellulose, washer and nut over the rod, screwing down the nut till the bag of cellulose is compressed against the hole. The cellulose bag fills up all parts of the hole, no matter how irregular, as the great value of the cellulose consists in its absorbing water and greatly increasing its volume. This elastic mass makes a tightly applied mat over the hole, which cannot be accidentally disturbed or displaced. Should the hole not be more than 10 inches wide and several feet long, a number of leak stoppers can be used side by side so as to gradually fill the hole.

Three sizes of arresters are used: No. 1 for holes from 1½ to 3 inches, No. 2 for holes from 3 to 6 inches and No 3 for holes from 6 to 10 inches.

In order to practically demonstrate the value of the leak arrester, the Franco-American Cellulose Company of 831 Arch street, Philadelphia, erected at their works a set of tanks pierced with holes of different sizes and shapes. The first experiment took place last year before a board appointed by the Navy Department and a number of naval officers and naval constructors, among whom were Lewis Nixon, chief constructor of the William Cramp & Sons Ship and Engine Building Company, and Captain Constance, naval *attaché* of the British Legation in Washington. The leak arresters were to be placed in three holes cut in the sides of an iron tank. The smallest hole was circular with burred edges and was 2½ inches in diameter; the next was hexagonal, about 10 inches wide, its area being about 72 square inches; the third was very irregular in shape and about 21 inches long, the average width being about 5 inches and the area 85 square inches. It being understood that the stoppers are intended to be used from the inside of the ship, the tanks were supposed to represent the sea and the holes or rents were located at a depth of 10 or 12 feet below the water line, with a corresponding water pressure. The tanks were kept full by means of a pump so as to preserve the same head of water during all the tests.

The time employed to effectually close the holes under a head of water of 12 feet was as follows :

1. 2½-inch hole	30 seconds.
2. 10-inch hole	1 minute.
3. 21-inch hole	3 minutes.

Another test made immediately after the above, using a water pressure of 9 feet, gave the following results :

10-inch hole	37 seconds.
21-inch hole	1 minute, 40 seconds.

During the latest tests made three leak stoppers were placed side by side, instead of two, in order to show that any number of leak stoppers can be employed to gradually decrease the leakage until the hole is under control.

It is said that after the test Constructor Nixon expressed his opinion as follows :

"The experiment was a signal success, and the holes were stopped in remarkably short periods. By the use of the Colomès leak stoppers and cellulose any leak in any vessel can be stopped before an appreciable quantity of water can rush in."

For holes of much larger area Mr. Colomès proposes to use a cellulose mat to be applied from the outside of the vessel. This mat resembles an ordinary mattress, filled with obturating cellulose and is made in several sizes. The side of the mat away from the side next to the ship is covered with water proof cloth in order to prevent too much water from filtering through the cellulose. On the sides and at the corners rings are fixed intended to receive guiding ropes. Such ropes should always be kept in readiness on the upper deck, bent and with the slack so arranged that they will fall under the vessel so as to hang from gunwale to gunwale. These ropes are to receive the mats as soon as a leak is discovered and located. The soft pliant nature of the cellulose lining of the mat enables the pressure of the water to force it into all parts of the opening, so that every crack is filled and the inflow automatically stopped.

The Franco-American Cellulose Company is now experimenting with a view to finding a non-combustible substitute for the woodwork of the cruisers and battle-ships of the navy.

EXPERIMENTS ON WIND PRESSURE.

The subject of wind pressure is one on which our knowledge at the present day is not only limited, but exceedingly vague, and carefully-made experiments, if but to investigate a single feature of the problem, are, therefore, of the greatest interest, and can hardly fail to add something new to our information. Mr. J. Irminger, C. E., Member of the Danish Society of Engineers, has determined, what it is believed no one before him has attempted to do, the amount of suction produced by a current of air striking a plane surface, or the surfaces of various bodies ; and the results of his experiments form the subject of a paper with the above title, read before that society in the early part of last summer. These results are remarkable in showing how very large a percentage of the total effect this suction is, not only through its action on the leeward side, but on the windward as well. In fact, when the angle at which the wind strikes a plane surface is small, nothing but suction is produced.

The practical importance of these experiments are evident ; they throw con-

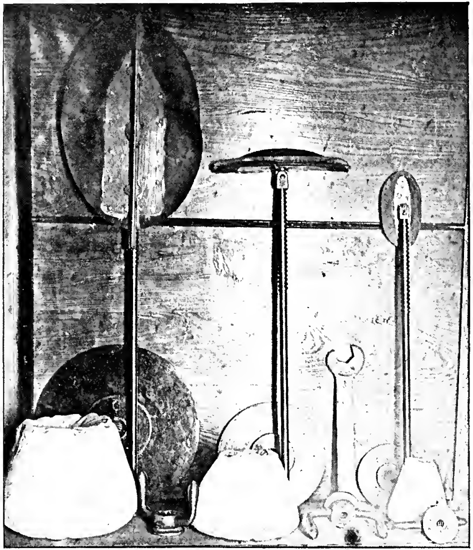

FIG. 1.

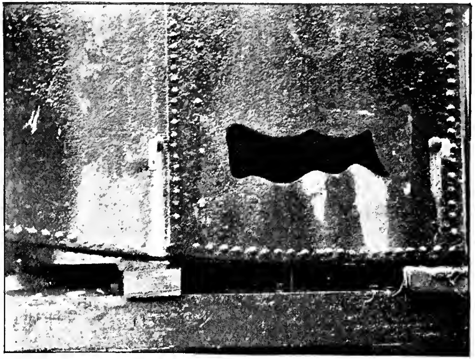

FIG. 2.

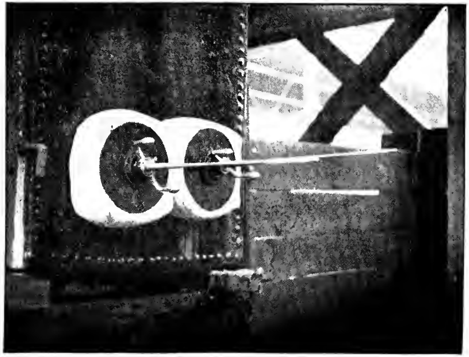

FIG. 1.—COMPLETE SET OF LEAK ARRESTERS.
FIG. 2.—SHAPE OF 21-INCH HOLE.
FIG. 3.—HOLE STOPPED.

siderable light on the subject of flight, which at present is engaging so much attention ; and in structural designing they point out the way to more rational methods. We have hitherto considered the resultant of the pressure only, but if that of the suction is also taken into account, the final resultant is changed both in amount and direction. Thus in the case of a roof, given below, the resultant of suction and pressure will tend to lift, and not overturn it, which is in accordance with experience.

Experiments on wind pressure have usually been made by causing the body subject to the pressure to revolve in still air. The author's experiments were made with a fixed body exposed to a current of air. This current was obtained by making an opening into a large chimney 100 feet in height and fitting to this opening a rectangular, horizontal wooden tube, 9 inches by 4½ inches in section, internally polished. The experiments were directed to ascertain the distribution of pressure over the surfaces both of planes (*i. e.*, solids of small thickness) and of bodies of various forms. Taking first the case of planes, the plane was represented in the experiments by two pieces of sheet iron, 4½ inches by 1½ inch, placed $\frac{1}{10}$ inch apart, and connected together along their edges so as to form a shallow, closed box. To the interior of this box a pressure gauge was connected by means of a small pipe. A number of small holes were made in both faces of the box of which one at a time was opened. By this means, the pressure guage registered the pressure at any desired point in the windward or leeward side of the box. The pressure-pipe formed an axle on which the box could be turned to any desired angle with the wind. By means of a valve in the wooden tube the velocity could be varied. The velocities employed were from 25 feet to 50 feet per second. Besides the plane above described, which occupied the full width of the tube, (and may therefore be considered to represent in the open air a plane whose width is very great in proportion to its length measured in the direction of the wind), another plane was experimented with, measuring only 2½ inches by 1½ inch. It should be remarked that the velocity of the wind was obtained from the observed normal pressures by reference to the ordinary tables. In the following tables based on the experiments, it should be especially noted that at small angles of incidence the effect of rarefaction on the leeward side (showing itself as suction) causes practically all the pressure on the plane, and that at so small an angle as 5° this suction is over $\frac{1}{5}$ of the total pressure (that caused by the wind direct, plus that caused by suction) on the same plane placed normally.

PLANE 4½ INCHES BY 1½ INCH (FULL WIDTH OF TUBE).

Angle of inclination of plane to direction of wind.	Proportion per cent. of total pressure produced on leeward side of plane, velocities of wind in feet per second being				Proportion per cent. of tot'l wind pressure to pressure on same placed normally (average).
	49.5	48.5	34	31	
5°	100	100	100	100	23
10°	82	83	90	91	45
20°	76	81	89	86	48
40°	65	67	68	70	75
60°	60	63	65	63	90
90°	56	58	56	59	100

PLANE 2½ INCHES BY 1½ INCH.

5°	100	100	100	100	12
10°	100	100	100	100	26
20°	95	99	91	90	52
40°	78	76	70	74	74
60°	60	55	55	56	90
90°	48	43	44	46	100

The total pressures agree fairly well with those of Professor Langley given in the Proceedings of the Royal Society for 1889. The variations are readily accounted for by the change in form, which has considerable effect, even with plane surfaces.

Doubtless in connection with the observed results at small angles of incidence, many readers will call to mind cases where, with a light beam wind and yards nearly square, a vessel under sail alone has made some pheromenal speed, unaccounted for except on the supposition that the real direction of the wind was from a point abaft its apparent direction. This, however, is no explanation at all, as will be seen by a little consideration. What is meant by the real direction of the wind, is only relative; it is the direction with regard to a fixed point on the earth's surface. The apparent direction of the wind is a resultant of two motions, and is the true direction with regard to a moving object on the earth's surface, namely, the ship. There is no more reason to take into consideration the direction of the wind with regard to a fixed point on the earth's surface, than with regard to a fixed point in space, and this latter is manifestly absurd. But much of the result of trimming yards fine for winds abeam is readily accounted for by the suction.

Probably the high speed of the ice boat is largely due to the same thing. The same is true of wind-mills.

It is observed that the bird holds its wing at an angle of 6° with the horizon; at this inclination the effect of the wind upon the under side of the surface is zero, while the suction acting on the upper side is equivalent to an upward pressure which sustains the bird. Moreover, the friction of the medium through which the bird moves is hereby reduced, and a current is produced acting towards the wing, and inclined upward at a small angle.

The following table gives the results of experiments on long prisms, placed with their axes at right angles to the wind. p is the total pressure on a long plane of width s placed normally to the wind, and of the same length as the prism. It has been shown that about 57 per cent. of p is due to rarefaction, causing suction on the lee side:—

Cross Section of Prism.	Total resultant Pressure in Direction of Wind.	Percentage due to Rarefaction.
Square of side s (wind parallel to side.)	0.95 p	43
" " " s (" " " diagonal)	0.79 p	76
Circle of diameter s	0.57 p	72
Rhombus, presenting an angle of 60° to the wind, length of side s	0.25 p	82
Equilateral triangle, side s (wind parallel to side)	0.59 p	42
Equilateral triangle, side s (presenting apex to wind)	0.42 p	86
Equilateral triangle, side s (presenting base to wind)	0.71 p	87

The following table refers to other than prismatic forms:—

Body Under Experiment.	Total Resultant Pressure in Direction of Wind.	Percentage due to Rarefaction.
Sphere	0.31 of total pressure on disk equal to great circle	77
Sphere distorted by elongation in the direction of the wind to double the diameter in length, ends pointed and symmetrical	0.08 of total pressure on disk equal to cross section	93

Body Under Experiment.	Total Resultant Pressure under Direction of Wind.	Percentage due to Rarefaction.
Cube of side s (wind parallel to edge)	0.80 of total pressure on disk, equal to face	22
Cube of side s (wind parallel to diagonal of face	0.66 of total pressure on disk, equal to face	55
Cylinder of height equal to diameter (wind perpendicular to axis)	0.47 of total pressure on square disk, equal to section through axis	50
Pyramid, square base of side h, height h (wind parallel to side of base)	0.78 of total pressure on disk, equal to maximum section perpendicular to wind	37
Pyramid, square base of side h, height h (wind parallel to diagonal of base)	0.55 of total pressure on disk equal to maximum section perpendicular to wind	55
Cone, height = diameter of base = h (wind parallel to base)	0.38 of total pressure on disk, equal to maximum section perpendicular to wind	50

The method used with these bodies is similar to that described for plane surfaces ; the different bodies are hollow and made of thin sheet iron ; they are about 4½ in. long, and provided with three holes in a row in the middle of one side. A hollow axis passes through the center, and communication is made with the pressure gauge in the same manner as before.

In the case of the cylinder, which was examined by boring a single hole in it and revolving it gradually through 360°, it was found that pressure existed only between 0° and 35°, when the effect became a suction. Similar results were found for the sphere.

Models were also experimented with representing buildings with roofs of various forms, and diagrams are given showing the distribution of pressure over leeward and windward sides. In all cases rarefaction on the side is quite as important a factor in the actual resultant force on the building as is the positive pressure on the windward side. The case of the pitched roof making angles of 45° with the horizontal on which a horizontal wind acts at right angles to the ridge is particularly worthy of note, and furnishes some food for thought. The normal pressure on the lee side due to suction is more than three times as great as that on the weather side. The resultant pressure on the two faces [neglecting the walls of the building] is inclined upwards and is about three and one half times as great as that on the weather side. On the weather side, the pressure is greatest near the lower edge, diminishes uniformly and becomes a suction near the ridge.

A REDUCIBLE LIFE-BUOY, AND THE GALIBERT RESPIRATORY APPARATUS.

[*Le Yacht.*]

Up to the present time solid bodies have commonly been used for rafts. Now the fact is, that the specific weight of the lightest of these rafts or floats is not much less than that of water, thus making it necessary to give them a great volume in order to obtain an indifferent floating capacity. M. Galibert has put them aside in constructing his buoy, which he has made of a special fabric perfectly water-tight and impermeable to water for several consecutive days. This reducible life-buoy has, when folded, a very small volume and an insignificant weight. It is easily inflated, and an air cushion is obtained, to which sailors have given the characteristic name of "turtle," owing to its shape and dimensions. The so-called personal buoy is so light, and presents such a small volume, that it may be kept in a small valise when the air is let out. Large buoys which have one thousand pounds resistance to submersion are so arranged that they can be immediately turned into a large raft, and be very useful in case of sudden shipwreck, taking the place of boats, which are often smashed in the breakers on landing, or which cannot be lowered owing to the position of the ship.

Another contrivance very useful in the equipment of a vessel is the "respiratory apparatus," which consists essentially of an impermeable bag constructed on the principle of the reducible buoy, and which contains a sufficient supply of air to permit the saving of life in an asphyxiating locality. This pure air reservoir fixed upon the back so as to permit of free motion, and having a tube connecting with the mouth, with a nose compresser or pince-nez, allows a person to breathe normally without taking in any of the vitiated atmosphere by which he is momentarily surrounded. Suppose, for instance, a case of fire on board the ship; the smoke reveals the locality of the fire, but prevents getting at its origin, and putting it out in the beginning. Provided, however, with the above apparatus, any one among the crew can go down in the hold, and thus arrest the progress of the conflagration. The same would be true in case of foul gases developing in coal bunkers or any other part of the ship. Both apparatus have been successfully tested, and have received the official sanction of the (French) Government. J. L.

BOOK NOTICE.

DESCRIPTION ET USAGE D'UN APPAREIL ÉLÉMENTAIRE DE PHOTOGRAMMÉTRIE. Par Le Commandant V. Legros. Paris, 1895.

Photogrammetry is the science of making photographs in which the perspective is *true*, and in which, therefore, the dimensions of the objects photographed can be readily measured. Its most general application is to surveying.

There are several claimants for the honor of inventing this application of photography to geodesy and, although of recent date, the history of photogrammetry is clouded with discussion. Frenchmen claim the honor for Colonel Laussedat, Germans for Dr. Meydenbauer. In Italy, the engineer Pio-Pagiurni identified his name name with the subject in a practical way, by making an extensive photographic survey of the Alps. That was in 1875 ; ten years later, Deville, in the United States, completed a similar survey in the Rocky Mountains that had lasted five years, and covered 63 square miles of territory.

Commandant Legros does not concern himself in his attractive little book either with history or polemics, but proceeds at once to explain, very clearly and concisely, the apparatus he has designed for photographic measurements. He disclaims any intention of adding a new instrument to the list that he says is already legion. "The point is this," he remarks, "we have sought only to make use of certain elementary means in such a way that they may be applied to all of the instruments now on the market."

A photographic survey is based upon the fact that a photograph taken with a suitable lens is a true perspective in which the focal length is the distance line. By drawing in the horizontal line and the principal vertical line, all the measurement taken on the ground may be taken from the photograph. The distance of the point of sight from the picture is the essential element in all the constructions.

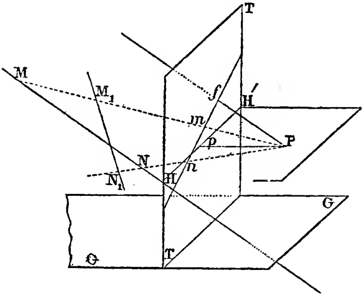

FIG. 1.

TT plane of picture.
P point of sight.
M a point in space.
m perspective of M.
If Pf is drawn parallel to MN, f is the vanishing point of the line.
PHH' plane of horizon.
p principal point.
HH' horizon line.
$Pp = d$ principal distance.

Every photogrammetric apparatus must be capable of tracing the horizon line, indicating the principal point and determining the exact focal length.

The construction of Commandant Legros' instrument will be understood from Fig. 2. The essential features of it are the graduated circle *K*, with its verniers and the ruled ground glass (*la glace quadrillée de precision*) in the swing-back *G*.

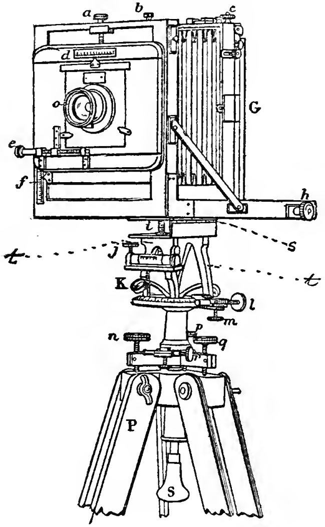

Fig. 2.

The camera is mounted on a double platform hinged at *s*, and supported by the uprights *tt*, fixed to the movable part of the circle. The axis of the swing-back is at right angles to that of the hinge, and the combination of the movements of the swing-back and hinge permit absolute vertical adjustment of the ground glass independently of the movement of the circle.

The ground glass is accurately divided into small squares by a double system of very fine parallel lines 1 cm. apart.

The lens has a vertical and horizontal movement by means of tangent screws *a*, *e*, the amount of which is measured in millimeters on the scales *d* and *f*. It is of the wide angle type and has a focal length of 5.51 in. to 5.707 in.; this corresponds to a plate 13 cm. by 18 cm. A lens of 20 cm. and an angle of 45° may be used with the same camera.

The instrument is easily adjusted, and as may be seen from the sketch, the attachments can be readily applied to any commercial outfit at slight expense. Among the other many advantages claimed for it by Commandant Legros, is the facility with which the horizon line and the principal vertical line are obtained, and the extremely simple method of determining the effective focal length.

A. G.

BIBLIOGRAPHIC NOTES.

AMERICAN.

AMERICAN ENGINEER AND RAILROAD JOURNAL.

Volume LXIX., No. 1, January, 1895. Water-Tube Boilers and their Application to War Vessels. Aeronautics; Captive Lookout Balloon on Board the French Battleship Formidable (illustrated).

No. 2, February. Water-Tube Boilers, etc. (concluded). Aeronautics; United States War Balloons (illustrated).

It is said that Captain Glassford "hopes to be able to take up the flying machine at the point it has reached through the remarkable experiments of Hiram S. Maxim, and build a machine that will carry a navigator through the air and at the same time will be under full control."

BULLETIN OF THE AMERICAN GEOGRAPHICAL SOCIETY.

December 31, 1894. The Cape York Iron Stone, by R. E. Peary, C. E., U. S. N.

CASSIER'S MAGAZINE.

December, 1894. The New American Navy. Some Possibilities of the Storage Battery. Producer Gas for Steam Raising. How Iron is Made. Edison's Kineto-Phonograph. Manufacturing Machinery—or Building It. John Ericsson, the Engineer.

February, 1895. Recent American Direct Connected Engines and Dynamos. Preservation of Wood. Direct Electric Driven Machines. The Incandescent Lamp of To-day. Combined Efficiencies of Mechanical and Electrical Machines.

ENGINEERING NEWS.

Volume XXIII., No. 2, January 10, 1895. The Ritchie-Haskell Direction Current Meter. The Cost of Hydrographic Surveys.

No. 4, January 24. The Puget Sound Dry Dock, Port Orchard, Washington. The Seattle Lake Washington Ship Canal. Chemical Methods of Preventing and Extinguishing Fires.

No. 5, January 31. Rustless Coatings for Iron and Steel.

No. 6, February 7. Preservative Coatings for Iron Work. The Loss of the Elbe.

No. 7, February 14. Recent Experiments on Wind Pressure.

ENGINEERING-MECHANICS.

December, January and February, 1895. High Speed Steam Engines. Blowing Engines and Machinery. Calculation of a Compressed Air Transmission when the Subsidiary Losses of Energy are Taken into Account.

IRON AGE.

Volume LV., No. 1, January 3, 1895. The Colomès Leak Arrester for Ships. The Maxim Oil-Hardening Process. Decimal Sheet Metal Gauge.

To supplant the present confusing and annoying gauges for sheet metal.

February 7. The Best Metal for Field Magnet Frames.

JOURNAL OF THE UNITED STATES ARTILLERY.

Volume IV., No. 1, January, 1895, Whole No. 14. Geometrical Construction of Gun Strains, by Professor A. G. Greenhill.

There is no real difficulty in making any geometrical construction that may be desirable in connection with guns if the necessity for the construction is apparent. The figures here given are at least as intricate as the formulas used in present works, and it is not probable that they will supplant the latter to any extent. Every problem in gun construction can be solved by the judicious use of the original two-term radial pressure and circumferential tension equations; and simple geometrical constructions in connection with these to keep clear the various steps are very desirable. This, however, is quite different from a thumb-rule method of illustrating an equation, a method which has no more real connection with gun construction equations than with any other simple equations.

Development and Construction of Modern Gun Carriages for Heavy Artillery. The Buffington-Crozier Disappearing Carriage for 8-in. Breech-Loading Steel Rifle. Shall the United States have Light Artillery? Coast Artillery Fire Instruction, etc.

JOURNAL OF THE FRANKLIN INSTITUTE.

January, 1895. The Animal as a Prime Mover, by R. H. Thurston. The Resistance to Corrosion of Some Light Aluminum Alloys.

In strong salt solution, pure aluminum is best, but the German silver alloy stands highest among the alloys.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

No. 73, January, 1895. The Military Academy. Physical Training in British Army. Artillery Practice at Shoeburyness. Some Thoughts on Methods of Attack.

SCIENTIFIC AMERICAN.

December 8, 1894. The Compass Field Glass.

December 15. Traveling Military Turrets. The Warship Atlanta and her Magazine.

December 22. Dry Dock at Port Orchard.

Will be the second largest dry dock in the world.

Trial of the Langley Aeoroplane.

It rose slowly in the face of the wind and sailed away for some distance.

December 29. The Cramp Ship Yards (illustrated). Equatorial Stand for Small Telescopes.

January 5, 1895. Torpedo-Boats for the Cruiser Maine. United States Battleship Maine. American Armor Plates. Improved Gatling Gun. Preservation of Propeller Shafts.

January 12. The Battle of the Yalu River.

January 19. The New Warships Texas and Oregon.

January 26. The Electroplating of the Hulls of Iron Ships. Repairing Chinese War-Ships.

February 2. Cannon Magnets.

At a distance of 300 feet a compass needle was deflected 3° (the cannon and compass being in an east and west line).

STEVENS INDICATOR.

Volume XI., No. 4, October, 1894. An Apparatus for Exploring Magnetic Fields as to Direction and Intensity, by Professor W. E. Geyer. The Determination of Carbon in Iron and Steel, by Professor T. B. Stillman. Experimental Determination of the Quickness of Action of a Shaft Governor, and Theoretical Consideration of the Influence of an Inertia Weight, by Professor D. S. Jacobus. The Manisman Process for Rolling Steel Tubes, by President Henry Morton.

THE UNITED SERVICE.

Volume XIII., No. 1, January, 1895. Recollections of Ericsson. The Organization and Administration of the Lines of Communication in War. Origin and Developments of Steam Navigation (continued). Notes on Photography, etc.

No. 2, February. China *versus* Japan. Organization of the Line of the Army. A Strange Wound. Origin, etc.

TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Volume XV., 1894. Theory of Direct Acting Steam Pumps and Its Results. Use of the Indicator for Continuous Records in Dynamometric Testing. The Cumulative Errors of a Graduated Scale. Notes on Belting. Recent Progress in the Manufacture of Steel Castings. A Comparison of the Mean Effective Pressures of Simultaneous Cards Taken by Different Indicators. Crucible Furnace for Burning Petroleum. On the Maximum Contemporary Economy of the High-Pressure Multiple-Expansion Steam-Engine, by Robert H. Thurston. Experimental Determination of the Effect of Water in Steam on the Economy of the Steam Engine. Constants for Correcting Indicator Springs that have been Calibrated Cold. Some Experiments on the Effect of Water Hammer. Steam Piping and Efficiency of Steam Plants. Mechnical Education, by Eckley B. Coxe, President of the Society.

> "If I wished to employ a young man in an engineering position, and had my choice between two equal in ability, age and health, of whom one thoroughly understood the fundamental principles of mathematics, mechanics, physics, chemistry and drawing, and the other was not so thoroughly trained in these, but had a college-shop experience and had gone through the regular courses upon the construction of locomotives, pumps, etc., and was able to discuss more or less intelligently all these different kinds of machinery, I should take the first. Although for the first year or so he might not understand as well as the other the details of the work he was engaged in, and might require more explanation and go slower, yet at the end of a couple of years, he would be far ahead."

A Note on Compressed Air. Power Losses in the Transmission Machinery of Central Stations. Cylinder Proportions for Compound Engines. The Theory of the Steam Jacket; Current Practice, by R. H. Thurston. Rustless Coatings for Iron and Steel. Corrosion of Steam Drums. Heat Units and Specifications for Pumping Engines. A New Recording Pressure Gauge for Extremely High Ranges of Pressures. Mechanical Draught.

FOREIGN.

ENGINEER.

Volume LXXVIII., No. 2031, November 30, 1894. English and French Quick-Fire Armaments. Wind Pressure. Peking (with map of city). Leading Articles: Flameless Explosives; Progress with Naval Contracts in Private Yards.

December 7. The Siegfried, German Imperial Navy. Leading Articles: The Machinery of Warships; Instability of French Battleships; Foreign Ship Canals.

DECEMBER 14. The Chilian Cruiser Blanco Encalada (illustrated). Leading Articles: The Machinery of Warships; Face-Hardened Armor in the United States.

DECEMBER 21. Leading Article: High Pressure Compound Engines. Report of the Secretary of the U. S. Navy.

DECEMBER 28. The present Status of Face-Hardened Armor, by Captain W. T. Sampson, U. S. Navy (extract).

JANUARY 4, 1895. H. M. S. Magnificent and Majestic. U. S. Torpedo-Boats.

JANUARY 11. Shipbuilding in 1894. Third-Class Torpedo-Boats for the United States Navy.

JANUARY 18. Science in 1894. Midship Sections of H. M. S. Magnificent and Majestic, and the Influence of Bilge Keels.

JANUARY 25. The French Battleships Magenta and Hoche. Leading Articles: Modern Electricity; Recent Trials of French Cruisers.

FEBRUARY 1. Leading Article: The Machinery of Our Ships of War.

"It may be said that these were all small matters. They were nothing of the kind. Each was great enough in itself to lead to the capture of the vessel by an enemy's ship. In the history of the fleet of the mercantile marine, if we except the very earliest experimental days, we find nothing to parallel this. We do not for a moment pretend to say that ships do not break down; but we do say that the failures are few and far between, and that the Navy would do very well if the record was equally satisfactory."

Japanese Guns at Yalu.

FEBRUARY 8. Argon (the lately discovered constituent of the atmosphere).

Chemically this is the most inert substance known. It is possibly monoatomic, the ratio of its specific heat under constant pressure to that under constant volume being 1.63. Gaseous argon has a density of 19.90.

The Floating of H. M. S. Majestic. An improved Cartridge Closing machine. Leading Articles: The Baden Krupp Accident; Direct Action High Pressure Pumps.

ENGINEERING.

VOLUME LXVIII., No. 1509, NOVEMBER 30, 1894. Combined Dynamo and Turbine.

A combined dynamo and turbine has recently been built by Messrs. J. P. Hall & Co., of the Blackriding Iron Works, Werneth, Oldham. The dynamo and turbine are mounted on the same bedplate. The dynamo is designed to give an output of 50 ampères at 80 volts, when running at 730 revolutions per minute. It has an armature of the Gramme wire-wound type, whilst the commutator segments are of hard drawn copper, insulated with mica. The brushes are of carbon, and the machine is so designed that the lead of the brushes may remain unchanged at all loads without sparking taking place. The field magnets are of wrought iron, and are shunt-wound. The electrical efficiency is about 86.33 per cent. The turbine is of the Girard type, and is intended to give 6 horse-power when supplied with 36 cubic feet of water per minute under a head of 120 feet. The guide ports are four in number, and can be closed successively by a revolving sluice, the spindle of which passes out through the turbine casing, and can be turned by an hydraulic cylinder, as well as by the handle.

Engineering in the United States Navy. The Bristol Recording Thermometer. Time Fuzes.

DECEMBER 7. The Machinery of Warships. Electricity on Shipboard.

DECEMBER 14. Canet Quick-Firing Artillery. The Strength of Short Boilers.

DECEMBER 21. The Guns for the New Spanish Cruisers. H. M. S. Magnificent. H. M. S. Ardent. Additions to the Navy.

DECEMBER 28. Torpedo Cruiser for U. S. Navy.

JANUARY 4 AND 11, 1895. The Application of Electricity to Working Ships' Turrets.

JANUARY 18. The Application, etc. (continued). Steam Life Boats. Flameless Explosives.

JANUARY 25. The Application, etc. (continued). The Engines of the Russian Ironclad Admiral Oushakoff. James Watt and Ocean Navigation.

FEBRUARY 1. The Application, etc. (concluded). The Coming Naval Estimates. The Cost of the French Navy.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

VOLUME XXXVIII., No. 201, NOVEMBER 15, 1894. Lessons from the Past for the Present. The Differentiation of a Naval Force: a Comparison. The Campaigns of Saxe.

DECEMBER 15. A New Method of Manœuvring "Controllable" Torpedoes or other Vessels when Absolutely Invisible to the Operator.

The position of the torpedo is plotted by a dead-reckoning method, the various courses being shown by an electrically controlled indicator. The question of irregularity of speed and current is not satisfactorily disposed of.

The Admiralty Flag. Naval Notes: Bow and Broadside Armament of Latest Types of French and English Battleships and Cruisers.

JANUARY, 1895. The Austro-Hungarian Manœuvres, 1894, Part I. The Vicissitudes of Regimental Colors, Part I. Notes on the Lee-Metford Rifle. Water-Tube Boilers. Naval and Military Notes.

The additional details of the Magnificent are interesting; also the new system of classification for the ships of the Italian fleet.

STEAMSHIP.

DECEMBER, 1894. Consideration on the Battleship in Action. Theory and Practice of Electrical Engineering. The Machinery of Warships.

FEBRUARY, 1895. The Design and Efficiency of Plant for the Transmission of Power by Electricity.

TRANSACTIONS OF THE NORTH OF ENGLAND INSTITUTE OF MECHANICAL AND MINING ENGINEERS.

Report of the Proceedings of the Flameless Explosive Committee. Part I.—Air and Combustible Gases.

UNITED SERVICE GAZETTE.

No. 3229, NOVEMBER 24, 1894. Places of Military Interest in the United States. The Machinery of Warships. Sea Power. The Magazine Rifle and its Tactical Use.

No. 3230, DECEMBER 1. The Training of the Navy. Capture of Port Arthur.

No. 3231, DECEMBER 8. The Engineer Staff in the Navy. Quick-Firing Guns and Projectiles.

No. 3232, DECEMBER 15. Coast Defence. Umpiring of Field Manœuvres. Effects of Modern Rifles. The Defensive Value of the Navy. Military Small-Arms of the World.

No. 3233, DECEMBER 22. Shipbuilding in the Royal Dockyards in 1894.

No. 3234, DECEMBER 29. The Surgical Significance of Modern Small-Calibre Rifles, I. The Fight Between the Yoshino and the Tsi-Yuen [on July 25]. The Effect of Modern Rifle Fire. Naval Rivalry. The Functions of the Army and Navy.

No. 3235, JANUARY 5, 1895. The Surgical, etc., II. A Naval Retrospect of the Past year.

The naval battle between the Japanese and the Chinese fleets off the Yalu, and subsequent events, conspicuously evidenced the advantage conferred by the possession of the command of the sea. Japan, once mistress of the sea, was able to land expeditionary forces practically at any portions of the enemy's coast line she desired, and the fall of Port Arthur was but a natural result, with after consequences the magnitude of which we are not even yet in a position to judge. The importance was strongly emphasized of having a sufficiency of dockyards well supplied with all the requisite appliances for speedily restoring ships damaged in action to a condition enabling them to resume hostilities, as also was the very great desirability of there being on board of a warship a sufficiently strong and highly skilled body of engineer officers and mechanics capable of executing unassisted all but the most serious repairs, thus often avoiding the necessity of withdrawing a vessel from a station where her presence may be all essential, and at the same time lessening the pressure on the dockyards. Had the Chinese Navy been in a condition to resume hostilities at an early date, China might very well have been saved the bitter humiliation she now seems inevitably doomed to suffer.

No. 3236, January 12. The Surgical, etc., III. The Navy League.

No. 3237, January 19. The Military System of America. Woodwork in Warships. The Personnel of the Navy.

No. 3238, January 26. Lessons of the Franco-German War. The Health of the Navy, I.

No. 3239, The Health, etc., II. J. H. G.

LE MONITEUR DE LA FLOTTE.

No. 48, December 1, 1894. The Inquiry Touching the Seagoing Torpedo-Boats. A New Petroleum Heating Method.

December 8. Radius of Action of our Warships.

December 15. Our Coast Defenses.

December 22. The Inquiry Touching the Seagoing Torpedo-Boats (continued). The Navy in Parliament.

December 29. The Inquiry Touching, etc. The French Navy in 1894.

January 1, 1895. The French Coaling Stations in View of the Madagascar Expedition.

January 12. Brueys and the Battle of the Nile. The Navy in Parliament.

January 19. The German Navy. The Extra-Parliamentary Board of Inquiry.

January 26. Our Colonies; Madagascar.

REVUE DU CERCLE MILITAIRE.

No. 47, November, 1894. Electric Searchlights and their Usefulness in Warfare (with sketch). Penetrating Power of the Modern Rifle. Infantry Practice (continued). Disciplinary Punishment in the Swiss Army.

NOS. 48, 49 AND 50, DECEMBER 2, 9 AND 16. Electric Searchlights and their Value for War Purposes (continued). Infantry Tactics (continued).

DECEMBER 23. Reorganization of the Italian Army. Electric Searchlights, etc. (ended).

DECEMBER 30. Lieut. Geraud's Field-Glass and Compass Combined. Infantry Tactics (ended).

JANUARY 5, 1895. The Regiments of the Cavalry Reserve and the Impressment Horses. The Loris Breast-Plate and the Dandeteau Rifle.

JANUARY 12. Platoon Instruction in the Artillery.

JANUARY 19. Long Distance Photography (sketches). Platoon Instruction in the Artillery.

JANUARY 26. Long Distance Photography (continued).

REVUE MARITIME ET COLONIALE.

DECEMBER, 1894. Our Commerce; our Countrymen in the Ports of the Atlantic, by Rear-Admiral de Librou. Influence of Sea Power on History, by Captain Mahan. Mission of the Upper Me-Kong; Report on the Trip of the Massie to Kemmarat, by Lieut. G. Simon. Description and Workings of the Hydraulic Apparatus of the 34-cm. Gun, Model 1887, in Closed Revolving Turrets, Mounted on Hydraulic Pivots, System Farcot.

"The late hydraulic apparatus furnished by M. Farcot, for vessels provided with closed turrets revolving on hydraulic pivots, differ to a great extent from those constructed up to the present. The installations described in this full and very interesting article refer specially to the cruisers Jemmapes and Valmy."

Vocabulary of Powders and Explosives (ended).

SOCIÉTÉ DES INGÉNIEURS CIVILS.

OCTOBER, 1894. Computation of Light Elastic Plates, and Action of Strings in Braced Ciment Beams.

NOVEMBER. Note on the Application of Aluminum to Naval Constructions. Seisms and Volcanoes. The Narrow-Gauge Roads in the Canton of Geneva.

DECEMBER. A Study of the Conveyance of Long Distance Energy through Electricity, and Electric Transmission by Continuous Currents. On the Experimental Determination of the Tension of Tie-beams in Arches.

LE YACHT.

No. 872, November 24, 1894 Effects of Artillery at the Battle of Yalu. A Reducible Life Buoy and the Galibert Respiratory Apparatus.

December 1. The China-Japanese War; the Battle of Yalu. The Taking of Port Arthur. The River Flotilla for the Madagacar Expedition.

December 15. The Navy in the Chamber of Deputies. The Positions of Belligerents at the Battle of Yalu.

December 22. New Maritime Incidents. The First-Class Cruiser Tourville.

December 29. The Battleship Magnificent. The Third-Class Cruiser Coêtlogon. The New Marine Boiler with Boiler-Tubes. A Table of the Ships in Commission on the 25th of December, 1894.

January 5, 1895. The War Navies in 1894. The Armored Coast Defense Vessel Jemmapes of 6600 Tons. The Stability of Route of Sailing Ships (A. Grenier). The Madagascar River Flotilla. English Constructions in 1894.

January 12. The War Navies in 1894 (E. Weyl). Stability of Route of Sailing Vessels. The Second-Class Cruiser Friant. Maritime Jurisprudence. Collision of Two Sailing Yachts.

January 19. Trials of War Ships (E. Weyl). Light Armor and its Substitutes. The Navy Yards and the New Constructions. The French Yachting of the Present Day. The U. S. Cruiser Minneapolis.

January 26. M. Felix Faure's Administration of the Navy Department. The French Yachting of the Present Day.

RIVISTA DI ARTIGLIERIA E GENIO.

Volume IV., November, 1894. Fortress Warfare (ended). On the Density of Air. Use of the Ordinary Tangent-Sight in Coast Firing. Study of a Quadrant with a Level of Precision. Artillery Action on the Battlefield in France, Germany, Austria and Russia.

December. On the Preservation of the Matériel in the Regiments of Field Artillery. Important Arguments Concerning Siege Ordnance The Use of Fortifications and Troops of the Engineer Corps on the Battlefield, and Lines of Investment. On the Approximative Research of the Center of Gravity of Ordnance, and the Projects in Course of Study (plates). Meteorology Applied to Military Art. Value of the Resistance of Air with High Initial Velocity.

RIVISTA MARITTIMA.

December, 1894. A Few Considerations Touching the Loss of the Victoria. Electric Navigation (continued). Political Parties and Revolutions in Corea. The Naval Battle of Yalu. The Madagascar Question.

January, 1895. Situation of the Italian Merchant Marine. Pleasure Sailing in 1894. The Battle of Yalu Once More. The Madagascar Question.

REVISTA TECNOLŌGICO INDUSTRIAL.

December, 1894. Explosions of Steam Generators. Tasks the Forensic Engineer Must Perform. Examination of the Plates (continued).

January, 1895. Explosion of Steam Generators, etc. Analysis of the Flour of Commerce.

BOLETIN DEL CENTRO NAVAL.

November, 1894. A Few Brief Historical Notes on Modern Naval Warfare. The Water-Tube Boiler. Vocabulary of Modern Powders and Explosives. Preliminary Notes for the Text of the Universal, and the Special Maritime Geography of the Argentine Republic (continued).

J. L.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE

Annual Series XXII., Volume XI. Tidal Phenomena in the Irish Channel. The Sailing Route from Sydney, Australia, to the Bismarck Archipelago, with a Description of the Coast of New Pomerania from Cape Gazette to Talili Bay, of the West and North Coasts of New Mecklenburg, and of New Lauenburg. Recent Observations with the Hydrometer. Justus Perthes' Sea Atlas. Minor Notices.

Meteorological Journals received during October at the German Observatory.

Weather Report of the German Coast for October.

Supplement. The Coast of Tonquin. Information from the Latest Sailing Directions for Atshin. On the Methods of Finding the Altitude of a Star. Wilmington, North Carolinia. Voyage from Valparaiso to Honolulu via Callao. Voyage from Callao to Honolulu. Voyage from Swatow to Shanghai. The Approach to Taiwanfu, Formosa, and to Bullock Harbor, on the Chinese Coast. Minor Notices.

Meteorological Journals received during November at the German Observatory.

Weather Report of the German Coast for November.

DEUTSCHE HEERES ZEITUNG.

Nos 93 AND 94. New Regulations for Infantry in France. Modern Reserves (continued).

No. 95, NOVEMBER 28, 1894. The Battle of Yalu (a Review of Admiral Sir George Elliott's views on the Battle).

DEBEMBER 1. Modern Reserves (continued). Madagascar. Modern Reserves (continued).

DECEMBER 5. Foreign Squadrons at the Seat of War in China.

The strength of the different squadrons was, at the end of November, as follows: English, under the command of Vice-Admiral Fremantle, twenty-six vessels of all classes, of a total tonnage of 65,323. Russian, sixteen vessels, 46,791 tons displacement, carrying 106 heavy guns. French, eighteen vessels, including those at Saigon, 39,590 tons displacement, carrying 120 guns. Exclusive of the vessels at Saigon, France has only twelve vessels of 27,700 tons displacement, carrying 93 heavy guns. The United States has a squadron of eight vessels, all modern, except the obsolete Monocacy. These vessels displace 17,350 tons, and carry 64 heavy guns. The number of R. F. guns carried by the several squadrons will be of interest, in view of the important part that this type of guns played in the battle of Yalu. Of these guns, the English squadron carries 28, varying in caliber from 12 to 15-cm., and 113 from 4.7 to 6.5, or a total of 141 guns, exclusive of revolving cannon and machine guns. The Russian squadron carries 135 R. F. guns of moderate caliber, of which nearly one-half are 3.7-cm. guns.

The French squadron carries numerous revolving cannon and machine guns, but only sixteen heavy R. F. guns, of 10 to 16-cm. caliber, and fourteen of 4.7 to 6.5-cm. caliber. The vessels of the United States carry 41 R. F. guns, including those of 3.7-cm. caliber. Italy has sent a squadron of three ships of a displacement of 7096 tons, and carrying 50 guns, including 22 R. F. guns of moderate caliber. Finally, Germany had a squadron of five old vessels, which has since been augmented by two modern ships. The former displace 7824 tons and carry 36 heavy guns, and not a single R. F. gun, and only 12 revolving cannon. The addition of the latter increases the tonnage to 13,864, the number of heavy guns to 58, of which 8 are R. F. guns. Besides these guns, the increased squadron carries 8 R. F. guns and 24 revolving cannon.

With the vessels en route to the East Indies, the strength of the combined foreign fleet is 78 vessels, of a total displacement of 199,714 tons, carrying 561 heavy guns. The fleet carries 350 R. F. guns, of which 90 are of heavy caliber. Japan's Navy sinks into insignificance in comparison.

Modern Reserves (continued).

DECEMBER 8. The Capture of Port Arthur. Modern Reserves (continued).

DECEMBER 12. French Artillery Material. Modern Reserves (continued),

DECEMBER 15. The Proposed Increase of the German Navy for this Year. Modern Reserves (continued).

DECEMBER 19. A Critical Review of the Fleet Manœuvres of 1894. Modern Reserves (continued).

DECEMBER 22. A Reply to the Brochure "Unser Kadetten Korps." Modern Reserves (continued).

DECEMBER 26 AND 29. A Reply to the Brochure "Unser Kadetten Korps" (concluded). Modern Reserves (concluded).

JANUARY 2, 1895. Frederick the Great. Field Fortifications and Tactics.

JANUARY 5. Field Fortifications and Tactics (concluded).

JANUARY 12. A Russian Criticism of the Corps of German Officers.

JANUARY 16. German Water-Ways. A Strategical and Tactical Review of the Battle near Pressburg, 22d July, 1866.

JANUARY 19. The French Army. A Strategical and Tactical Review of the Battle near Pressburg, 22d July, 1866.

JANUARY 26. Military Attachés. A Strategical and Tactical Review of the Battle near Pressburg, 22d July, 1866.

MILITÄR WOCHENBLATT.

NO. 103, DECEMBER 8, 1894. Review of the Grand Manœuvres of 1894 in Germany (concluded). The Battle of Orleans (concluded). Mobilization of the Russian Army. The Strength of the French Army for 1895.

DECEMBER 12. The Battleship in the Battle off the Yalu River. The Mobilization of the Russian Army (concluded).

DECEMBER 22. A Brave Deed. The Effect of Field Artillery. The Riding School.

DECEMBER 29. The Effect of Field Artillery (concluded). The Riding School (concluded).

JANUARY 16, 1895. The Mobility of Artillery. Cereals for the Sustenance and Support of an Army. The Latest Changes in the Organization of the Italian Army.

JANUARY 19. The German Cavalry, 1870-71. The Mobility of Artillery (concluded). Shrapnel Fire of Field Artillery (a study). The Reverse Side of a Militia Army.

JANUARY 23. Concentration in Infantry Attack.

JANUARY 30. Changes in the Organization of the Army Corps of the Russian Army.

SUPPLEMENT TO MILITÄR-WOCHENBLATT.

VOLUME I., 1895. Von Moltke's Views on Flanking Manœuvres. The Disposition of Reserves in Battle.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOLUME XXIII., No. 1. Speed and Turning Efficiency of Ships of War.

A discussion of the relative advantages of these qualities in actions between fleets and between single ships. The writer holds that the advantage will be with the ship or fleet that possesses the greatest turning power, and advocates in the construction of battleships increased steering power by the use of side rudders, to be operated either conjointly with or independently of the main rudder.

Naval Events in the War between China and Japan, including the Battle off the Yalu River.

A review of the events at sea, and a discussion of the battle off the mouth of the Yalu river.

The Pebal-Schaschl System of Electric Signal Telegraph for Ships. The Best Tactics to Develop the Fighting Power of the Gun, Ram and Torpedo in Actions between Ships, Groups and Fleets (translation). Gibraltar as a Base for the English Fleet. The German Naval Budget for 1895. The Dutch Naval Budget for 1895. The French Naval Budget for 1895. The French Battle-Ship Brennus. The Drezevecky Under-Water Launching Apparatus.

The trial of this apparatus on board the French cruiser Surcouf was successful.

Proposed Cruisers 3rd Class for the English Navy. Torpedo-Boat Destroyer Ardent. The English Cruisers Conquest and Carysfort. A New Torpedo Launching Apparatus Adopted in the English Navy. Launch of the Russian Armored Ships Poltava and Petropavlovsk. Petroleum as Fuel on Board Russian Warships.

The new armored cruisers Rostilav and Rossia will have their boilers fitted to burn petroleum ; and, if they prove successful, other ships will be similarly fitted.

The Trial of the Zalinski Pneumatic Gun in England. Death by Electricity.

No. 2. The Austrian Cruiser Empress and Queen Maria Theresa.

This protected cruiser has been recently completed and added to the Austrian Navy.

The English Naval Manœuvres of 1894. The French Naval Manœuvres of 1894. A Method to Determine the Position without the use of Logarithms. The Best Tactics to Develop the Fighting Power of the Gun, Ram and Torpedo. Defenses of Sarent. The Corinth Ship Canal. The Italian Battleship Re Umberto. The English Battleship Magnificent. The English Torpedo Boat Destroyers Ardent, Conflict and Dragon.

The first, on her official trial, developed a mean speed of 27.84 knots in six runs. The last two were launched at White and Laird's ship yard on December 15, 1894.

The French Submarine Boat Gustave Zédé. New French River Gunboats.

These boats have been designed and are building for use in the Expedition against Madagascar.

Proposed Increase of the Portuguese Navy. New Battleship for the Brazilian Navy. A New Man-of-War Harbor in France.

It is proposed to build a harbor at Port en Bessin.

A New Type of Whitehead Torpedo for the English Navy. A New Escapement for Watches. The Balloon at Sea. H. O.

REVIEWERS AND TRANSLATORS.

Lieutenant HUGO OSTERHAUS, U. S. N.	Lieutenant J. H. GLENNON, U. S. N.
" ALBERT GLEAVES, "	Professor JULES LEROUX.

THE CAPTURE OF WEI-HAI-WEI.

Reliable news in regard to the details of the capture of Wei-Hai-Wei is exceedingly scarce, and even the account of the sinking of Chinese vessels, previous to the surrender, is somewhat mixed.

The Japanese official account of the sinking, as we gather from a contemporary, runs thus :

" On the night of February 4, Monday, the first torpedo flotilla guarded the western entrance to Wei-Hai-Wei harbor, while the second and third flotillas, after the moon had set, made their way into the harbor through the eastern entrance. Having got inside the harbor, the boats torpedoed, and destroyed the large ironclad Ting-Yuen, whilst the bottom of the cruiser Ching Yuen is supposed to have been damaged. On the night of the 5th, the first torpedo flotilla renewed the attack, and torpedoed, and sank the cruiser Chih-Yuen," (this should probably be Ching-Yuen, as the Chih-Yuen was sunk in the battle of the Yalu) "and the large ironclad Chen Yuen" (this is an error, as the Chen Yuen was afterwards surrendered by Admiral Ting), "the Wai (Lai ?) Yuen, and one of the gunboats."

The following, from the letter of a naval officer stationed on board a cruiser at Chefoo, will possibly indicate the answers to a few whys and wherefores unexplained as yet in the newspaper accounts with regard to the capture of Wei-Hai-Wei. The writer was not present on the ground, so of course writes only from hearsay evidence.

Wei-Hai-Wei fell on Monday, February 18 ; that is, on that day the final surrender took place. The day before, Admiral Ting, and the general in command of the forces, and a commodore whose names I forget, committed suicide. Admiral Ting took opium, the general swallowed gold (had to take opium afterwards to finish the task), and the commodore shot himself. This, that is, the shooting, is a very rare thing in China, as the Chinese like to leave their bodies intact.

Nothing was destroyed ; the Japanese allowed the garrison to go, even furnishing a ship (one of the captured Chinese men-of-war) to convey the dead bodies of Admiral Ting, and the others, and the living frames of the various

European officers in the Chinese service to this port (Chefoo). The Japanese got the Chen-Yuen (7300 tons), two or three smaller men-of-war, six gunboats (Rendel system), and nine torpedo-boats (mostly Thornycroft), a machine-shop, the forts and their guns (a few were disabled by the Chinese), six bran new rifled breech-loading mortars for high angle fire (Krupp, 28 cm.) and a large amount of coal, food, clothing, rifles, ammunition, etc.

The defense of the place was almost farcical. We hear that the Japanese lost only a couple of hundred men on land and sea. They made no efforts to force the island forts, but turned their attention to frightening Chinese. In this, they were most successful; the sailors and soldiers (Chinese) absolutely refused to fight any longer.

Perhaps you will be amused at the account of the attack of February 7. This was given to me by an officer in the Chinese service. On the morning of this day, all the Japanese fleet placed themselves in front of the east entrance to Wei-Hai-Wei, and turning on their steam sirens and whistles, they fired all their guns (many of which were loaded with powder only) at the east entrance and the Chinese fleet. The forts on the mainland (also in possession of Japanese, having previously been captured by a Japanese army commanded by Field-Marshal Count Oyama) also opened fire, and the noise was terrific. The Chinese torpedo-boats turned and ran back through their own fleet and out through the other entrance and then dispersed, every man running for himself. The European officers, and the few men who remained in the island forts (the majority ran and hid) opened fire on their own torpedo-boats and sunk one of them. The others were all run ashore, the crews deserting, and running inland. The Chinese fleet started to follow, but did not go all the way out, and so were not lost. Not a shot from the Japanese during this "attack" struck any of the Chinese forts or ships. It was simply a scare, and a most successful one.

The famous torpedo-boat attack of the Japanese was directed by signals (lanterns, English Morse code) made by Chinese in the pay of the Japanese, who were serving in the Chinese forts.

The cowardice, ignorance and knavery of these Chinese "warriors" is almost beyond belief. They will run from a dozen men if they are only given the chance. The only obstacle the Japanese have is the weather. The winter is very severe; many days it is so rough that their ships have had to put out to sea, and their men have been unable to leave their quarters.

OFFICERS OF THE INSTITUTE,

1895.

Elected at the regular annual meeting, held at Annapolis, Md., October 12, 1894.

President.

REAR-ADMIRAL S. B. LUCE, U. S. N.

Vice-President.

COMMANDER A. S. SNOW,* U. S. N.

Secretary and Treasurer.

LIEUTENANT J. H. GLENNON, U. S. N.

Board of Control.

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LIEUTENANT HUGO OSTERHAUS, U. S. N.
PROFESSOR N. M. TERRY, A. M., PH. D.
LIEUTENANT J. H. GLENNON, U. S. N. (*ex-officio*).

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*Captain Philip H. Cooper, U. S. N., was elected Vice-President December 15, by the Board of Control, Commander Snow having resigned.

ANNUAL REPORT OF SECRETARY AND TREASURER OF THE U. S. NAVAL INSTITUTE.

To the Officers and Members of the Institute :

Gentlemen :—I have the honor to submit the following report for the year ending December 31, 1894.

Itemized Cash Statement.

Receipts During Year 1894.

Items.	First Quarter.	Second Quarter.	Third Quarter.	Fourth Quarter.	Totals.
Dues	$190 09	$1059 78	$327 00	$461 42	$2038 20
Subscriptions	43 05	198 70	371 75	47 60	661 15
Advertisements	123 75	206 25	70 00	148 14	548 10
Interest	117 50	9 00	45 50	120 09	292 09
Sales	119 05	143 75	40 70	76 25	379 70
Life membership fee	30 00	..	30 00	..	60 04
Binding	..	16 85	10 04	4 00	30 89
Protested check made good	..	..	..	6 00	6 09
Premium on foreign check	..	..	05	..	05
Half cost of Nos. des. by fire	..	..	..	57 94	57 94
Totals	$623 44	$1634 33	$895 04	$921 44	$4074 25

Expenditures During Year 1894.

Items.	First Quarter.	Second Quarter.	Third Quarter.	Fourth Quarter.	Totals.
Printing	$550 00	$1165 67	$880 48	$367 78	$2963 93
Salaries	270 00	230 00	310 00	280 00	1090 00
Postage, registering, etc.	18 78	53 85	53 57	25 99	152 19
Expressage	2 60	4 55	1 95	5 00	14 10
Freight and hauling	3 69	4 19	3 42	2 96	14 26
Expense, business trips	2 75	5 15	..	5 40	13 30
Expense on articles	8 35	2 00	..	..	10 35
Office expenses	1 05	5 94	.	..	6 99
Stationery	10	..	94	1 00	2 04
Binding	16 45	..	..	22 50	38 95
Prize (annual)	100 00	..	..	..	100 02
Gold medal	13 50	..	..	..	13 50
Purchase of back numbers	4 40	..	..	..	4 40
Telegraph, telephone, etc.	..	58	29	15	1 02

EXPENDITURES—*Continued.*

Items.	First Quarter.	Second Quarter.	Third Quarter.	Fourth Quarter.	Totals.
Engraving medal and for case..	..	$4 00	..	..	$4 00
Purchase of Magazine for copy.	..	50	..	..	50
Advertising..................	..	..	$32 80	..	32 80
Protested check...............	..	..	6 00	..	6 00
Purchase of back numbers......	..	..	..	$6 50	6 50
Disct. on foreign money order..	..	03	..	..	03
Totals....................	$991 67	$1476 46	$1289 45	$717 28	$4474 86

SUMMARY.

Balance of cash unexpended for year 1893..........................	$5216 39
Total receipts for 1894....................................	4074 25
Total available cash, 1894................................	$9290 64
Total expenditure for 1894................................	4474 86
Cash unexpended January 1, 1895............................	$4815 78
Cash held to credit of reserve fund.........................	132 89
True balance on hand January 1, 1895......................	$4682 89
Bills receivable for dues 1894.............................	694 85
“ “ “ back dues..........................	795 00
“ “ “ binding............................	26 40
“ “ “ subscriptions......................	137 45
“ “ “ sales..............................	34 00
Value of back numbers (estimated)..........................	2000 00
“ “ Institute property.............................	100 00
Total assets..	$8470 59

The liabilities of the Institute consisted on January 1st of the bill for printing No. 72, which had not been delivered on that date.

RESERVE FUND.

United States 4 per cent. Consols, registered......................	$ 900 00
District of Columbia 3.65 per cent. registered bonds................	2000 00
Coupon bonds..	450 00
	$3350 00
Cash in bank uninvested....................................	132 89
Total Reserve Fund.......................................	$3482 89
Number of new life members...	3

MEMBERSHIP.

The membership of the Institute to date, January 1, 1895, is as follows: Honorary members, 6; life members, 109; regular members, 576; associate members, 199; total number of members, 890.

During the year 1894 the Institute lost by death, resignations and dropped, 38 members. 63 new members' names were added to the rolls—50 regular, 13 associate; 2 regular, and 1 associate member became life members.

MEMBERS DECEASED SINCE JANUARY 1, 1894.

LIFE MEMBERS.

Brush, Geo. R., Medical Inspector, U. S. Navy, November 29, 1894.

REGULAR MEMBERS.

Nes, D. S., August 13, 1893.

Much, G. W., Naval Constructor, U. S. Navy, August 17, 1894.

Bridgman, W. R., Captain, U. S. Navy, September 14, 1894.

Merriman, E. C., Captain, U. S. Navy, December, 1894.

Garvin, John, Lieutenant, U. S. Navy, December, 24, 1894.

Street, G. W., Asst. Naval Constructor, U. S. Navy, January 11, 1895.

ASSOCIATE MEMBERS.

Bole, J. K., January 8, 1894.

Balch, Geo. T., Colonel, April, 15, 1894.

Comly, Clifton, Major, Engineer Corps, U. S. Army, April 17, 1894.

Turtle, Thomas, Major, Engineer Corps, U. S. Army, September 18, 1894.

Copeland, C. W., February 5, 1895.

PUBLICATIONS ON HAND.

The Institute had on hand at the end of the year the following copies of back numbers of its Proceedings:

	Plain.	Bound.		Plain.	Bound.
Whole No. 1	104	..	Whole No. 5	119	..
2	241	..	6	..	..
3	58	..	7	6	..
4	146	..	8	34	1

	Plain.	Bound.		Plain.	Bound.
Whole No. 9	38	1	Whole No. 41	260	19
10	4	..	42	108	19
11	215	1	43	159	3
12	52	1	44	57	10
13	2	..	45	42	19
14	4	..	46	50	19
15	..	..	47	31	19
16	224	1	48	54	18
17	1	..	49	19	17
18	105	1	50	62	17
19	108	1	51	38	18
20	126	1	52	58	16
21	223	1	53	152	34
22	268	1	54	4	4
23	178	1	55	58	17
24	183	1	56	544	55
25	1137	44	57	22	20
26	210	80	58	6	7
27	300	27	59	17	10
28	4	15	60	..	1
29	210	9	61	194	18
30	246	4	62	143	16
31	39	53	63	233	44
32	18	173	64	40	19
33	10	162	65	127	18
34	5	..	66	6	16
35	140	5	67	11	15
36	275	29	68	200	9
37	200	24	69	227	16
38	243	1	70	228	18
39	233	1	71	276	16
40	35	115			

1 Vol. X., Part 1, bound in half morocco.

Very Respectfully
J. H. GLENNON, *Lieutenant, U. S. Navy,*
Secretary and Treasurer.

SPECIAL NOTICE.

NAVAL INSTITUTE PRIZE ESSAY, 1896.

A prize of one hundred dollars, with a gold medal, is offered by the Naval Institute for the best essay presented on any subject pertaining to the naval profession, subject to the following rules :

1. The award for the prize shall be made by the Board of Control, voting by ballot and without knowledge of the names of the competitors.

2. Each competitor to send his essay in a sealed envelope to the Secretary and Treasurer on or before January 1, 1896. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary and Treasurer, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Board.

3. The successful essay to be published in the Proceedings of the Institute : and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Board of Control ; and no change shall be made in the text of any competitive essay, published in the Proceedings of the Institute, after it leaves the hands of the Board.

4. Any essay not having received honorable mention, may be published also, at the discretion of the Board of Control, but only with the consent of the author.

5. The essay is limited to fifty (50) printed pages of the Proceedings of the Institute.

6. All essays submitted must be either type-written or copied in a clear and legible hand.

7. The successful competitor will be made a Life Member of the Institute.

8. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

By direction of Board of Control.

J. H. GLENNON,
Lieut., U. S. N., Secretary and Treasurer.

ANNAPOLIS, MD., *January* 1, 1895.

Vol. XXI., No. 2. 1895. Whole No. 74.

PROCEEDINGS

OF THE

UNITED STATES

NAVAL INSTITUTE.

VOLUME XXI.

EDITED BY J. H. GLENNON.

PUBLISHED QUARTERLY BY THE INSTITUTE.

ANNAPOLIS, MD.

PRESS OF
THE FRIEDENWALD COMPANY,
BALTIMORE, MD.

The writers only are responsible for the contents of their respective articles.

CONTENTS.

NOTICE.

Annapolis, Md., *February* 6, 1895.

Having carefully read the six essays submitted in competition for the prize offered by the U. S. Naval Institute for the year 1895, we have the honor to announce that, in accordance with Article XI. of the Constitution, the prize is awarded to the essay bearing the motto "The best of prophets of the future is the past," on Tactical Problems in Naval Warfare, by Lieut.-Commander Richard Wainwright, U. S. Navy.

Honorable mention is accorded in the order named to the essays bearing the mottoes (1) "Le temps de guerre est arrivé," on A Summary of the Situation and Outlook in Europe, an Introduction to the Study of Coming War, by Richmond Pearson Hobson, Asst. Naval Constructor, U. S. Navy; (2) "Simplicity," on Suggestions for Increasing the Efficiency of Our New Ships, by Naval Constructor Wm. J. Baxter, U. S. Navy; (3) "*Οἱ μὲν θεοὶ πάντα ἀνθρώποις πωλο͂υσιν, ὁ δὲ μισθὸς ἔργον*," on The Battle of the Yalu, by Ensign Frank Marble, U. S. Navy.

B. F. TILLEY,
Lieutenant-Commander, U. S. Navy.
URIEL SEBREE,
Lieutenant-Commander, U. S. Navy.
C. E. COLAHAN,
Lieutenant, U. S. Navy.
G. L. DYER,
Lieutenant, U. S. Navy.
H. OSTERHAUS,
Lieutenant, U. S. Navy.
N. M. TERRY,
Professor, U. S. Naval Academy.
J. H. GLENNON,
Lieutenant, U. S. Navy.
Members, Board of Control.

NOTICE.

The prize essay for 1895 and the essay receiving first honorable mention have been held till the present number in order to allow of a reasonable time for printing and discussion. The remaining articles receiving honorable mention will appear in the next number.

By direction of the Board of Control.

J. H. Glennon, *Lieutenant, U. S. Navy,*
Secretary and Treasurer.

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. XXI., No. 2. 1895. Whole No. 74.

PRIZE ESSAY, 1895.

"*The best of prophets of the future is the past.*"

TACTICAL PROBLEMS IN NAVAL WARFARE.

By LIEUT.-COMDR. RICHARD WAINWRIGHT, U. S. Navy.

In the study of the naval battles of the past we may learn of the many tactical problems that have arisen, and how they were solved by the great commanders of fleets; how they met with success, or the causes of their defeat. The causes are frequently obscure, as so many varying circumstances surround the tactical problem, and it is difficult to set forth the problem and its solution cleared from outside interferences. The best of tactics have failed, at times, to win success because of a change in circumstances or because of faulty instruments. And, at times, hard fighting has prevented failures that were earned by faulty tactics. Yet through all the thread of truth can be followed, and the rules that have led most frequently to success in naval warfare can be traced out for future guidance when acting under similar conditions.

The difficulty met with in discussing the problems that may arise in the future is the great change in the vessels, in the weapons and in the motive power. All have made such strides forward in the march of improvement, since any great naval combats were fought, as to cause some to think that past battles can furnish no guide to the tactics of the present or future.

The first steam tactics prepared for the student in the art of war were mainly drawn from studies of tactics under sail, the necessary modifications being made to suit the change in motive power. It was evident that many of the old rules still applied; that the uncertainty produced by being obliged to rely upon the wind having been eliminated, it became possible to be more exact in the performance of manœuvres and more regular in formations. To concentrate a large portion of your force on a small portion of the enemy's was still the thing for which to strive and more than ever likely to bring success. As sail was partially a source of reliance, injury to the engines was not entirely fatal; and the knowledge of how to handle a vessel under sail was a necessity. The facility with which vessels could be handled under steam and the ease with which concentration could be accomplished gave them such an immense superiority over vessels dependent upon sail alone that it caused sails to fall gradually into disuse. Superiority in speed and in handiness were still elements of advantage that facilitated the following of the tactical rule of concentration.

The improvements now came so rapidly, and the differences between the new and the old weapons became so great that the minds of naval men were unsettled. It became difficult to draw any analogy between an old fleet and one of modern times. The tactical relations between the various weapons and between the different types of ships were constantly changing, and it was difficult, if not impossible, to estimate the tactical values of these varying quantities. Each tactician had his favorite weapon and favorite type of ship, and used a few facts and many suppositions to support his theory. Armor was placed in all positions, guns of many calibres were carried, vessels were built of all sizes and carried weapons of various kinds, and the kinds of powder and projectiles supplied were no less numerous. Some tacticians relied on ramming, some upon torpedoes, and some upon the use of guns as the principal weapons, putting the others in the background as auxiliaries.

While many of the main principles of tactics remain as unchanged as the laws of strategy, nothing is more certain than the fact that tactics change with the weapons and with the change in their relative values as tactical weapons. Such principles as to strike immediately when the enemy is surprised, when not in battle formation, or when changing formation; to bring a large portion of your force to bear upon a small portion of the force of the enemy; and that the flanks and the rear are the usual weak points of a formation, are unchanged, and have been known since tactics were first a subject of study by naval men. But the best formations in which to carry out these maxims, and the proper evolutions to bring them into effect, change with the change in the weapons.

Sir Howard Douglas formulated an excellent system of tactics for steam vessels; but steam was at that time only an auxiliary to the sails, and the well accepted rules for sailing vessels were modified only so far as was necessary to take full advantage of the new motive power. Being no longer dependent upon the direction and the force of the wind, the formations were more elastic and the concentrations were made with more precision. The guns carried in broadside were the weapons both for attack and defense, and boarding was the only other way of carrying on a conflict. Boarding could be resorted to, except in very rare cases, only after the opposing battery had been almost, if not completely, silenced.

Shell guns came into use and were improved, as was the steam engine; but there was no cause to alter the tactics. Such was the destructive effect of shell guns that the wooden sides no longer afforded any protection to the fighting crews, and the vessels themselves were liable to destruction after being under fire a short time. Naturally a more efficient protection was sought, and ironclads came into existence. Now commenced a contest for supremacy between guns and armor that continues at the present day. Guns were built that pierced the armor, then came thicker and heavier armor, then more powerful guns. To carry the increased weights vessels increased in size, and yet the guns had to be decreased in number, and the armor had to be concentrated on vital portions in place of covering all the above-water sides.

With heavily armored vessels naturally came the idea of running down the weaker vessels; besides, the crews of the few guns and the vitals of the ship being well protected, the necessity for a more decisive weapon led to the idea of the ram. The gun lost in relative value as a tactical weapon, and the ram came to the fore. Tactics must be changed to use this weapon to the best advantage. The enemy was no longer to be crushed with the broadside, but with the bow. It was no longer a concentration of fire but one of iron beaks that was necessary, and columns, lines and groups were urged by their several advocates.

Torpedoes grew slowly into prominence, and the auto-mobile torpedo became a weapon with which tactics was forced to deal. The large, unwieldy battle-ships with few guns, loading and firing slowly, had but little power of offense or defense against small torpedo-boats. Admiral Aube and his followers were to maintain naval supremacy by a mosquito fleet: and the tactics best adapted to torpedo-boats were the rage. The inability of these boats to keep the high sea or maintain their speed in any but smooth water soon cast a damper upon this misplaced enthusiasm, and it was recognized by most naval minds that victory would still remain on the side of the fleet of battle-ships, and that there was no cheap or easy road to naval supremacy.

Rapid-fire and machine guns, with electric search-lights, were developed as the necessity arose, and the battle-ships were again able to protect themselves near shore as well as at sea; and heavily armored vessels became necessary for coast defense as well as for sea fleets. Again the gun was raised in its relative tactical value.

The battle-ship is now fitted with torpedo tubes, and many believe that they can be used with such effect as to make an attempt to ram dangerous to the vessel making it, so that this further use of torpedoes has helped to increase the tactical value of the gun.

The cruiser has developed side by side with the battle-ship. The displacement devoted to armor in the battle-ship is devoted to motive power and fuel in the cruiser. They have increased greatly in speed, and upon the advent of rapid-fire guns it became necessary to furnish them with some protection, and we have gone from unprotected cruisers to partially protected cruisers, to protected cruisers, and to belted or armored cruisers. The latter are fit, usually, to take their place in the line of battle, and are battle-ships of great coal endurance with comparatively light armor; as, on the other hand, the coast defense vessel is a battle-ship of small coal endurance but heavily armored. The one sacrifices more displacement to the power of making long cruises, while the other sacrifices in favor of protection.

The protected cruisers depend upon a steel protective deck, numerous water-tight compartments, minute subdivisions, with water-excluding material, for protecting the buoyancy of the vessel, and depend upon shields, etc., for the protection of the crew.

There are many vessels of special design and constructed for various purposes, and on which other weapons than the gun take the principal place. They each require their peculiar tactics to develop best the weapon they carry.

At the present day it looks as if the great strides in the progress of both vessels and weapons had ceased for a time, and that the changes to be expected in the near future are not great, but that the tendency is to settle down to fewer types of vessels and to less rapid improvements in these and in the weapons. If this is true, the tactics that are correct for the present time will remain so for a number of years, or until some new start is made in the improvement by sudden changes in vessels or in weapons. The general character of the vessels and the tactical value of the weapons may be considered fixed for our purposes.

The various changes in tactics corresponding to the changes in weapons may be traced in the writings at the time the improvements developed. Of course there is considerable overlapping, particularly at the time when the three weapons were supposed to be nearly equal in value. The more enthusiastic would seize eagerly upon a weapon early in its career, or rather in its new stage of development, and the more obstinate would hold on longer to a weapon in its decline. There were times when the gun was distinctly the principal weapon, and then tactics required that vessels be fought with their broadsides presented to the enemy. Again there were times when the ram had far the greatest number of adherents, and then they required the vessels to present their bows. The ram and torpedo required close quarters. Admiral Colomb, R. N., preferred the ram in 1871 and the gun in 1884; Admiral Fremantle, R. N., the ram in 1880 and the gun in 1886; Commander Sturdee, R. N., the torpedo in 1886 and the gun in 1894. The weight of opinion is now strongly in favor of the gun as the principal weapon.

Take two vessels equal or nearly equal in all respects. Let one attempt to ram and let the other continue circling, but endeavoring to avoid the ram. Know thoroughly their tactical diameters for various helm angles, and plan the fight as in still water. It will require quite serious mistakes in the one that endeavors to avoid the ram before his adversary can strike a bad blow. Allow even quite a difference in speed and handiness between the two vessels, and yet how difficult for the superior to ram the inferior. Allow the inferior vessel to make slight changes in her speed, almost if not quite imperceptible to her adversary, and see where the would-be rammer will bring up. Then take these vessels under ordinary conditions of wind and sea, their speed and tactical diameter changing as they change their position relative to the wind and sea, and note the difficulty of estimating the speed or the size of the turning circle on your own vessel, and the still greater difficulty of estimating that of the enemy. Does not ramming under such circumstances become a matter of chance? Imagine the captain of a ship attempting this delicate operation from the conning tower, his view limited and partially obscured by smoke, his helmsman with no view at all, nothing to steady his helm by except possibly a small compass that is liable to jump with each fire of the adjacent guns. Most of us have noticed the difficulty, when piloting, in steadying the head of a ship if the helmsman could not see ahead and was obliged to rely on a good compass for steadying or meeting with the helm. This difficulty must be greatly increased in a conning tower, and yawing must result at a time when the slightest deviation may change a vessel from the destroyer into the destroyed. Again, there is the danger that may appear greater or less to the tactician as he has greater or less faith in torpedoes, of coming within the range of that weapon. Certainly the danger from the torpedo and the danger of being rammed instead of ramming prevents the ram from being the principal weapon.

The gun has been greatly developed in power, in range, in accuracy and in rapidity of fire. The questions that remain somewhat unsettled at the present time are the kind of powder to be used, the proportion between the length of a gun and the calibre, and the proportion of rapid-fire guns to those of larger calibre. It appears to be quite definitely settled that 13 inches is the limiting calibre of guns to be carried on battle-ships, as in guns of this size the weight has become as great as can be reasonably carried on a man-of-war, and the time occupied in loading as long as could be permitted in battle. The largest guns must be handled by machinery, which adds another weak point to the battle-ship. Many are of the opinion that 10 inches should be the limiting calibre, and that the guns should be capable of being handled by man power as well as by steam, air or electricity. They believe that there is sufficient penetration by the projectiles of high-powered 10-inch guns at reasonable ranges, and that the reduction in weight and in time between fires more than makes up for decreased penetration.

Lieutenant Meigs, who has given so much attention to the development of gunnery practice and is one of the best authorities on the tactical value of the gun, suggests the rule that within reasonable limits the vessels should carry guns proportioned to their own protection. This rule is fairly well followed, for the heavily armored coast-defense vessel carries a few large calibre guns, and the protected cruiser numerous guns of smaller calibre. The armored vessel also carries a number of smaller guns; the smaller rapid-fire and machine guns to drive off torpedo-boats and other small craft; the larger rapid-fire guns to attack unarmored ends and to crush lightly protected vessels. In the cruiser the calibre is kept somewhat larger than required by the rule, for the sake of gaining in explosive force of the shell, the consequent gain in damage inflicted being sufficiently great, up to certain calibres, to more than balance other disadvantages.

The length in proportion to calibre has been increasing with the improvements in powder, thus gaining higher velocities, therefore greater penetration and greater range. This increase in length was made possible by adopting breech-loading devices, and requires slow-burning powders. It would seem as if it might be better to follow the spirit of the rule above mentioned more closely, and in cruisers to decrease the length of the larger guns and increase their calibre. This might be done without unduly increasing the height of the trajectory for moderate ranges, and with the larger shell thus gained the explosive force would be considerably increased. It is logical to arm cruisers to fight cruisers, and other things being equal, the cruiser throwing the larger shell would be more powerful than one armed as at present.

Smokeless powder suitable to the smaller calibres has already been manufactured successfully, and the development is in the direction of smokeless powder for all calibres. Numerous attempts, more or less successful, have been made to fire shell charged with high explosives. They have been sufficiently successful to start an alteration in the distribution of armor, causing it to be spread over a larger surface. Comparatively thin armor, that is, armor that would not stop an ordinary shell, will cause those charged with high explosives to burst outside, causing little or no damage. Improvement is to be sought in the shell more than in the character of the high explosive, as the more perfect the shell the further it will penetrate before detonating the charge.

The improvement in armor has been great, from wrought-iron to composite, to homogeneous steel, to nickel steel, and now to Harveyized nickel steel; but the improvements in the gun and in the armor-piercing projectiles have been greater. At present a peculiar point has been reached; when the resistance of the armor and the penetrating power of the a. p. shell are nearly equal, a very slight difference in the shell makes a great difference in the effect. Where a shell well formed, with perfect point and smooth exterior, will remain intact and almost uninjured after piercing the armor, a similar shell having about the same physical characteristics, but slightly less well formed, will break up with only a slight penetration upon the same armor. It would appear as if the high velocities with which the shell is driven through the armor transmits by vibrations, where there are slight inequalities on the surface of the shell, a tremendous force that disrupts the smaller mass of the shell, but is distributed throughout the larger mass of the armor plate without causing serious injury. Is there not some analogy between this fact reached with high velocities in the shell, and the importance of wave resistance when high speeds are made by the vessel? Experiments are now being made by covering the point of the a. p. projectile with some comparatively soft and readily fused metal, such as lead; the idea being to gain entry with the point uninjured, the lead being melted by the heat developed upon impact.

The modern tendency is to increase the proportion of rapid-fire guns. Where armor is carried sufficiently heavy to resist them there must be unarmored ends and lightly protected guns for them to attack; and the larger calibre rapid-fire guns are capable of attacking all but the heaviest armor. The decision of the battle may rest with the heavy slow-firing guns, and yet it may be decided by the numerous rapid-fire guns before the heavy guns have been loaded and fired more than a few times. Guns of position are usually necessary to reduce a fortress, but no battle could be brought to a successful conclusion in modern times without light artillery.

The questions formulated by Mr. Clowes in No. 70 of the Proceedings of the United States Naval Institute are very pertinent to naval warfare, and indirectly affect tactics, as they are founded upon the consideration of the battle-ship in action. An attempt to answer them, or at least to indicate the direction in which correct answers are to be sought, is almost necessary before seeking for correct solutions of modern tactical problems.

The first question is a most important one: "*Would it be prudent for any battle-ship to go into an engagement cleared for action merely as she is generally cleared for it during peace practice or manœuvres? Is any clearing for action that is not most complete and thorough, of use as an instruction?*"

It would be imprudent evidently to go into an engagement without making all the preparations that are possible in the time allowed by the circumstances of the case. That there are many precautions omitted in the ordinary exercise of clearing ship for action we all know. I have been told of an occasion when the admiral commanding the English Mediterranean fleet signalled to his vessels one morning to report when cleared for action, and some of them did not report until noon of the next day. Some of this time must have been occupied in rigging a torpedo defense, nets, booms, etc., as the vessels were at anchor; but many things ordinarily omitted must have been done to fill up so much time. More lately, the Detroit, Commander Brownson, at Rio Janeiro, when she was to steam in and protect our merchantmen while proceeding to a wharf, against the Brazilian rebel fleet, took about two hours to clear for action. The officers and men worked hard, and everything was done that experience or fertility of resource could suggest. It was far more thorough than would be practicable in an ordinary drill.

It may be necessary to prepare for action with but little warning. Many essentials can be accomplished in a comparatively short time. By exercise these are done as a matter of routine. The men become acquainted with their stations and duties, and, being accustomed to perform the work, there is no undue excitement. The work will be done more quickly and there is less liability of omitting important particulars than if no such drill were prescribed.

It is well once in a while to make a thorough business of it; but there must be many precautions that can be taken which could not be included reasonably in an ordinary drill. It might be said that a battle-ship should be prepared at all times, at least during war or when likely to encounter the enemy, but this is not practicable; for instance, time was spent on the Detroit in rigging up and protecting ready magazines, and in adjusting caps of nose fuzes, without which it would be difficult to keep up a running fight with rapid-fire guns. It would not do to keep shell on deck in sufficient quantities for any great length of time; and as hammocks, awnings, etc., are used for the protection, the time for which they can be used is limited. Ready magazines may be constructed and properly protected. Base fuzes may do away with the necessity of shifting the cap; but plenty of work can be found to occupy the time to advantage. Protection can be extemporized for the bridge and other exposed points. The boats may be moved or more securely stowed, filled with water and otherwise protected. A longer time will thus be occupied than would be reasonable for an ordinary drill; but it would be wise to occasionally devote the time necessary to thorough preparation.

The amount of time that the circumstances have permitted to be devoted to preparation may directly affect the tactics of vessel or fleet; for without an ample supply of ammunition ready to hand it would be unwise to enter into a close running fight, and it would be good tactics to manœuvre for a distant engagement until ready magazines could be prepared.

The second question is: "*What should be done with a ship's boats upon clearing for action? Would it be prudent to hoist them all out, and leave them in tow of the steamboats, a few miles astern; or would it be prudent to expose them to the enemy's gun-fire in their position on the booms and elsewhere? Preservation of the boats and reduction to the lowest possible quantity of the splinters* *flying about the deck must be considered on the one hand; on the other hand, the possible escape of one or more boats from the effects of projectiles, and the importance, if it can be secured, of having something ready for immediate lowering, deserve attention.*"

In whatever way this question may be handled tactics will not be involved. It certainly does not seem wise to leave the boats astern, for the rear in an action is liable to change frequently and become the front or be in any other direction, tactically speaking. At sea it would be better to carry the boats. If there are any that are so situated that their splinters would endanger a gun's crew, and the men could not be protected from them, it would be well to put them overboard, risking their recovery at the end of the action. Ordinarily the splinters could be prevented from flying by filling the boats with water and surrounding them with their sails. It would be well to improvise protection against machine-gun fire; but in a close, long-continued action they would be rendered useless in all probability for immediate lowering. It might be wise to have a collapsible boat stowed below the water-line or behind heavy armor. Before going into action in a harbor, or when preparing for one just outside your own harbor, it would be well to send the boats to a safe place, trusting to the boats of a tender being sent if necessary.

The third question is: "*What is likely to be the effect upon a ship's anchors, of a successful attempt to use the ram? What the effect upon them, of the ship's heavy forward guns if fired nearly ahead and with some depression? Is it or is it not important that you shall be in a condition to anchor at the close of an engagement?*"

Undoubtedly a ship's anchors are liable to be torn from their place when a successful attempt to ram is made. This is one of the risks necessary to run when ramming. The bow may be smashed in or the ram twisted. It is not likely that one vessel will ram another without both receiving injuries. The chains should always be unbent when going into action, to prevent unnecessary danger. As to the effect of the heavy guns when fired with depression, it would depend somewhat upon the distance from the muzzle of the guns from the deck. The anchors should be so secured as to stand the blast if the decks can resist it. With proper securing bolts, the anchors can be lashed so as to hold as long as the decks. It may be quite important to be able to anchor at the close of an engagement. If on a lee shore with damaged engines and bad weather threatening, anchoring may be the only means of safety; as was the case with the English fleet after Trafalgar. A spare anchor might be a most valuable thing to have at hand, but weights must be considered, and no precautions will prevent naval warfare from being dangerous for lives and material.

The fourth question is: "*Have you a thoroughly workable scheme whereby you can at once provide the proper substitute for any officer who may be killed or wounded, no matter in what part of the ship he may be stationed? Can you instantly make good the chain of authority throughout the vessel, no matter in what link it may be broken? Can you do this repeatedly? Can you do it if two or three links should break at once? Does your method of making good these breaks leave your chain dangerously weak in places, or only shorter as a whole?*"

All of these questions except the last could be answered correctly in the negative, as to answer them in the affirmative would be to expect to be able to perform impossibilities. In the various divisions and in the many parts of the ship the train of authority may go from senior to junior officer, through petty officers to the lowest in the seaman grade. It may happen that an important division or station will be left without an officer to command. Undoubtedly it will be weakened; but we can trust that there will be found among the brave, intelligent and well drilled seamen one who can carry on the fight until an officer can be found to take command or even until the action is over. It would be impracticable to be shifting stations and divisions during an action so that the most experienced officer should always hold the most important station. During a naval engagement the chain is liable to become dangerously weak as well as dangerously short, in spite of all precautions. Fighting cannot be made a safe business.

The succession to command is the most important portion of the chain of authority to preserve unimpaired. The position that the executive officer may happen to occupy at the time of an injury to the captain is a matter of vital importance. The United States Naval Regulations say of the executive, on page 119, Article 523, that "In battle he shall look after the general working of the armament, and from time to time repair to any part of the ship where his duty may be performed to the best advantage." If the executive supervises the general working of the armament, his position at any one time is uncertain, and when he is wanted to assume command he may not be found readily, and when he does assume command he may have but little knowledge of events outside of his own ship, unless this regulation is interpreted, as it should be properly, to mean from the conning tower deck or bridge, except in cases of emergency. Otherwise the position of other vessels or their condition may be entirely unknown to him. This would be always an unfortunate condition of affairs, and under certain circumstances could only result in disaster. The removal of the captain by wounds or by death during action must be always quite a serious event. No matter how well the next in command may be acquainted with the scheme of action, the captain's methods, and the surrounding circumstances, there must be a short time elapse before he can hold the reins firmly. Should the ship be about to ram or be attempting to escape the ram of an opponent at the time, a slight wavering or uncertainty during the time the second brain was taking the command relinquished by the first, might be sufficient to turn a position of safety into one of imminent danger, or to turn victory into defeat. The latitude allowed by the regulations is necessary, as emergencies might arise requiring the presence of the executive in any part of the ship; but they must not be construed too liberally, for during the greater part of a battle his duties can be performed to the best advantage in positions not far from his commanding officer. The Germans station the executive, the second in command, on a lower deck, in a position of comparative safety. Here he is unlikely to be injured by the same accident that incapacitates the captain, and he can always be found; but his knowledge of passing events must depend upon such reports as he may receive from time to time, and it would take some minutes before he could act intelligently should he be called upon to assume command. The second in command should be near the captain, so as to learn from him his scheme of action from time to time. He should be able from his station to keep himself informed of the sequence of surrounding events. He should be sufficiently near to prevent any interregnum, where he could notice the fall of the captain and where he could exercise at once the command that devolved upon him. And yet he should be in such a position as would render it unlikely that both of them should be injured at the same time, and where he can render efficient service superintending the general working of the armament. When the captain is on deck the executive should be in the conning tower, and if the captain be in the conning tower the executive should be on deck under some protection.

When piloting is necessary the navigator must be at or near the wheel to conn the ship and keep her from running aground, as the captain would probably need all his faculties to fight his ship properly. When no piloting is required he could be stationed in some comparatively safe and central position, from which he could be called readily to assume the duties of executive should it become necessary. The senior watch and ordnance officer should not be called from his duties, unless required to take the position of executive.

The fifth question is: "*To what extent do you propose to rely upon voice-tubes, electric wires for lighting, firing and signalling, helm indicators, engine-room telegraphs, etc., in action, and what provisions have you for finding substitutes at an instant's notice for any or all of them?*"

Voice-tubes or telephones are absolutely necessary for the proper command of a modern vessel. The distances are too great and the passages are too intricate to admit of relying upon messengers, and a chain of messengers is as liable to damage as a voice-tube, and the liability of errors arising is greater in the former than in the latter. The number of voice-tubes can be increased easily, and different stations arranged for their use; but the size of the crew is limited, within reason, to the berthing capacity of the ship. Some messengers are necessary, but the number of the crew that can be spared for such purposes is limited. There will be many times during war when the strain upon the crew will be great, and it might easily grow excessive if they were not properly berthed so as to be able to get the necessary rest when suitable opportunities occurred. Lighting by electricity is more in danger of interruption than by lamps; but when there are sufficient dynamos, and the battle circuits are properly run, this danger is reduced to a minimum. Lanterns should be kept filled and trimmed ready for lighting at all points where light is a necessity. Helm indicators and engine-room telegraphs add to the precision with which orders can be delivered and executed. They should always be supplemented by gongs and voice-tubes. It must be remembered that injury to the conning tower may injure the steering wheel and the communications at the same time, and that other stations must be provided with means of communication to the engine-room, and also to the tiller-room, at which place it may become necessary to steer the ship. It is extremely doubtful whether the electric control for firing broadsides is an advantage or not. It must not be depended upon; but there should be an electric signal by drop-shutter or otherwise, so that the captain may be informed when any guns are put out of action. It might modify his tactics considerably should he be informed that a portion of his guns were rendered useless. There might be great choice as to which broadside to turn to the enemy; or if sheering to increase the strength of fire, the helm to use would be regulated in accordance with the location of the damaged guns. For night signalling, rockets, Very's signals and torches would be provided always to take the place of electricity, should that means of signalling fail.

The sixth question is: "*How much more or less complicated and delicate gear have you in your ship upon which you would not think of depending if you were going into action? Do you use it at present? Is it wise to use it if you would not think of depending upon it?*"

This question appears to refer to the subjects of the fifth question already considered. All methods of signalling, securing communication with the various parts of the ship and operating the machinery should be as reliable as possible and the same used under ordinary circumstances as would be used in action. This is necessary to secure familiarity with the gear and reasonable certainty of working in time of battle. Simplicity and strength should be sought for; but it must be remembered that a ship of war is a complicated machine, and that there are of necessity many parts which are delicate and liable to be injured. To multiply these unnecessarily would be a serious mistake, but there are few machines more complicated or more delicate than man himself, yet his services are indispensable. A compromise on this question as well as on many others that arise in the consideration of a man-of-war is necessary. There has been a tendency abroad, but not at home, to sacrifice too much of the strength of moving parts in order to economize weights. Guns may be handled more swiftly and accurately by machinery than by hand, and yet a damaged man may be replaced when it would be impossible to replace or repair the machine. Where to draw the line will always require anxious thought and numerous experiments. The tendency will continue to be in the line of an increase in the amount of machinery for replacing hand power as improvements are made and designs perfected.

The seventh question is: "*What provisions have you for making or answering signals in action? Have you any protected station for your signalmen?*"

The ordinary provisions for signalling in action are quite inadequate, and in no direction is improvement more necessary; but whatever method may be used, shapes, semaphore, or flags, protection must be provided for the signalmen. In some of the accounts of the Yalu river fight it is stated that the Chinese were obliged to remain in their weak formation because all the signal halliards were cut early in the action. It may be believed that this was not the only reason for the helplessness of the Chinese fleet, but it must be recognized that as signals are necessary for the proper handling of a fleet, protection for the signalmen, at least, must be provided against machine-gun and small-arm fire.

The eighth question is: "*What effect may be anticipated should a hostile projectile strike a fuzed shell in your racks, or a charged torpedo? How does a knowledge of what may happen in such an event influence your arrangements for keeping up a supply of ammunition to your more exposed guns, and for using your above-water torpedo tubes?*"

If a projectile should strike a fuzed shell it would be very likely to explode; but there is no reason why the remaining shells should explode. Not very long since an army caisson exploded and some of the shells must have been exploded by the concussion of the others; but it is probable that they were badly fuzed, and such an accident is not liable to happen with the navy fuze. Under any circumstances it is necessary to have a supply of ammunition for your guns, and the risk must be run, only it can be narrowed as much as possible by using permanent or improvised protection.

The reservoir of a Whitehead torpedo would make quite a serious explosion if struck by a projectile, and it is probable that both the Howell and the Whitehead charges would be detonated by an exploding shell, if not by the concussion of a projectile. For this reason it is unwise to carry charged torpedoes in unprotected above-water tubes, as they may possibly prove more damaging to your own vessel than to the enemy. Of course this refers to battle-ships and to cruisers, not to torpedo-boats.

The ninth question is: "*How would a suspicion that your bow tube might at the moment contain a live torpedo influence your decision, should an opportunity for ramming present itself?*"

My bow tube would not contain a live torpedo so long as the motive power of the ship remained uninjured. A bow tube is of little value on a battle-ship. It should only contain a charged torpedo when the motive power has been so impaired as to render ramming impossible and being rammed probable, and then the bow would be the least useful place to have one.

The tenth question is: "*Is there from your battery-deck an up-draught which would quickly free the battery from the gases of any explosion that might occur there? What consequences are to be apprehended there or elsewhere from the gaseous products of certain high explosives?*"

The first part of this question evidently refers to the earlier type of battle-ship. It is hardly probable that much of an up-draught could be procured. From the experiments with modern high explosives it is hardly probable that many would escape the effect of the concussion or of being asphyxiated by the explosion of a shell so charged in a casemate or other gun enclosure.

The eleventh question is: "*Can you get in your torpedo-net defenses sufficiently to enable you to manœuvre your ship, without the necessity of employing your men outboard, in such a manner as to mask much of your own gun-fire, as well as to expose the men to the fire of the enemy? If not, do you purpose, in war-time, to ever use your net defenses when you are liable to sudden attack?*"

No known net defense can be rigged in securely without exposure of men and important loss of time. The torpedo-net is mainly useful when coaling and repairing within the radius of the enemy's torpedo-boats, or when attacking a harbor where there is no liability of being attacked in return by other battle-ships. It would be criminal to use them when able to steam and liable to be attacked by other ships.

The twelfth question is: "*Do you realize the continuous nature of the strain likely to be put upon executive officers by the conditions* *of modern warfare? Have you ready any scheme whereby this strain may be as much as possible equalized, and whereby both officers and men may husband their strength and nervous energy to the best advantage? For how long do you consider that a crew could stand the wear and tear of maintaining a position, say within fifty miles of a great port in which lay a hostile fleet and a large flotilla of torpedo-boats?"*

If you have a properly organized force, with a reasonable proportion of cruisers and torpedo gunboats or catchers, you can, by making proper tactical dispositions of your forces, prevent any excessive strain upon officers or men. In fact, in no other way will a tactician have a better opportunity to show his ability than in so disposing his vessels as to prevent sudden alarms and undue tension from being inflicted upon his entire fleet. In the daytime, except in foggy weather, and even in bright nights, but few lookout vessels would be necessary to prevent a surprise; but on dark nights and in thick weather it would require all the cruisers and gunboats to guard the battle-ships, and numerous lookouts would be necessary on all the vessels of the fleet. The circumstances may be too varied to admit of fixed rules, and with only a small proportion of unarmored fast vessels the strain must be great under any circumstances. If fifty miles away, the battle-ships can cruise under low steam, or remain at anchor, with heavy banked fires, during the day in clear weather or during bright nights. The hostile port must be watched closely by three or four light vessels, the number depending upon the size and character of the entrance guarded. At night these outguards must be cautioned to examine headlands, wooded points, etc., as closely as the enemy's batteries will permit, to prevent torpedo-boats from sneaking along the land. Outside of these, in a central position, within easy signal distance, the main guard of torpedo-catchers must cruise at night. In the daytime one or two cruisers to pass back the signals can take their place. Within five or six miles of the fleet again will be stationed two or three torpedo-catchers, to watch for torpedo-boats that may have passed the outguards. Between the fleet and the inguards the main body of inguards will be stationed at night. The guards of the night previous will be stationed where there is the least chance of their being subjected to sudden attacks. If the position being maintained is a harbor, the mouth will be closely guarded and the fleet anchored so that it can steam out and be drawn up in battle formation at a point where it has ample sea-room, soon after the notice of the movement of the enemy's heavy vessels. It would only be practicable to thus maintain a point fifty miles from a hostile fleet, when it was only necessary to watch and keep in touch with the fleet of the enemy. But if masking or blockading the enemy's fleet, it would be necessary to hold the fleet nearer the hostile port and to be kept underway at all times. Then the point fifty miles away might be maintained for coal, ammunition and other supplies and for repairs. In foggy weather the line must be drawn more closely around the port, and the main guard should join them in picket duty. The work would then become most arduous, and signals must be carefully arranged to prevent the attacking of friends. The cruising ground must be carefully laid out to prevent the necessity of too frequent signalling that would betray the whereabouts of the guard to the enemy. Sound signals only would be possible, and they could be changed from time to time, using the steam whistle, the boatswain's call and the bugle. If a harbor is the point maintained, picket-boats and torpedo-boats must swarm at the entrance. It would hardly be possible for the enemy to make an attack with his heavy vessels in a thick fog, and if he did, the torpedo-boats and torpedo gunboats should be able to defeat him. If the point were an open roadstead, it would be practicable to anchor the fleet when there were ample torpedo-boats for protection and when the weather was suitable for handling them. But if the sea were too rough for the boats, the fleet should stand out from land at a moderate speed, followed by the cruisers and gunboats in a formation with a broad front, and running out for an agreed upon length of time, then upon the signal being made, standing in at a slow speed with the cruisers spread out in front. A column of cruisers should connect the line of cruisers with the battle-ships, to pass sound signals and to keep touch in the fog. In this way of disposing the vessels the strain should not be excessive, unless an inordinate amount of foggy weather is encountered, as the greater fatigue would fall upon the younger officers and men who should be more able to endure it, and being in the smaller boats could be the most readily relieved, and would be from necessity more frequently relieved for coaling, etc.

Should you be blockading the port or masking the fleet it would not be practicable to closely guard the enemy during foggy weather with the heavy vessels. For if he can feel his way out he can keep in close order and attack everything he sees or hears, and when separated make for a pre-arranged rendezvous. With the use of torpedo-boats and torpedo gunboats his attempt to escape could be made highly dangerous, if not impossible, and the heavy boats should be kept well off the port.

The thirteenth question is: "*What will be the effect upon the occupants of a conning tower, even if it withstand the blow of a heavy projectile,* (A) *from the concussion,* (B) *from the displacement of the fittings? Should a commanding officer attempt to fight his ship from the conning tower? If not, how should she be steered, and from what position can the captain enjoy the necessary view, while still maintaining communication of some sort with his officers?*"

The question of the conning tower is a most vital one. It has been discussed partially already in the question (No. 4) about maintaining the chain of command. We have some previous experience from which to judge, viz., the reports of the commanders of our monitors during the war. They all spoke of the difficulty of handling their vessels with the limited view afforded by the conning tower, especially during the smoke of battle. The effect of concussion can only be estimated. Wooden mantlets prevent direct contact that would be fatal at the time of the blow, deaden the force of the concussion by the intervention of an air cushion, and prevent injury from flying bolts. A vessel might be well handled from the conning tower, provided it were well constructed, if it were manœuvring against one vessel only; but if the vessel were in a fleet, or were manœuvring against several vessels, it is difficult to imagine how the captain could obtain a sufficiently all-around view to fight his ship from the conning tower. There would be little likelihood of the same commanding officer being able to carry through an engagement unless he were afforded some protection, for without it he would be sacrificed, probably, at close quarters, at a time when it would be most disadvantageous to change the officer in command. There should be several protected stations, at least one on each bow, from which the captain could fight his ship. These stations must be clearly visible to those inside the conning tower, and they should be connected with the conning tower by gongs, telephones or indicators, or by all. They should also be connected with the steering station in the tiller-room and with the engine-room. The captain could communicate by signs with those in the conning tower under many circumstances, but must be able to have recourse to other methods at times. The conning tower should be accessible from the deck, so that the captain can enter when desirable, and his officers and messengers can leave it to communicate directly with him. Even with all these facilities, to accurately handle the ship he will require great experience under service conditions. The captain, the officer at the conn, and the helmsman must work in unison. The finest display of the seaman's art will be the handling of a battle-ship in action. Seamen are more than ever necessary, and without a high order of intelligence, guided by experience, the immense ship, with its numerous guns, powerful engines and intricate machinery, will be wasted in the combat.

The fourteenth question is: "*To what extent, if any, can glass over dials, lamps, lanterns, etc., be depended upon in the event of a heavy explosion in its vicinity? To what extent, if any, can horn or talc be substituted for it? Is it advantageous, or otherwise, to have a brightly lighted battery on the occasion of a night action?*"

The first portions of this question might well be the subject of experiment, and could be exactly determined without difficulty. Thicker glass than used ordinarily might be found advisable where it was practicable to sacrifice some of the light. The last portion of the question can have but one correct answer. No one who has had experience on board ship, who has looked out of a lighted pilot-house or chart-room at night, can fail to answer in the negative. The gunner's view is frequently seriously limited in the daytime; at night from a brightly-lighted battery he would see hardly anything, and to bring his sights on anything but a brightly-lighted object would be an impossibility. Only so much light as is necessary for loading the guns and setting the sights should be used, and that should come from behind the gunner, and care should be taken that it is not reflected from the side or from the gun into the gunner's eyes.

The fifteenth question is: "*Will it in all cases be advantageous to use smokeless powder? What provision is there for the production of smoke should it be needed to serve as a screen to leeward?*"

A battle-ship must have a clear view, and therefore under most circumstances must be seen, so that smokeless powder prevents being taken unawares by the enemy and mistaking him for a friend, as well as giving a clear target for the guns. There have been several smoke-producing inventions for army use that might be useful in preparing for an attack to be made by your own torpedo-boats. All the smoke needed can be produced also by a raft with a burning tar-kettle.

The sixteenth question is: "*What are the possible defenses of a ship underway, against a torpedo that is approaching her? What is her safest position* (A) *if moving slowly,* (B) *if moving at speed, supposing that she cannot in time move out of the line of fire? What is the effect upon a torpedo of the explosion of a heavy charge under water within a short distance of it? What provision have you for the explosion of such a charge at short notice, in or near the path of an advancing torpedo?*"

Under the circumstances mentioned, the helm and rapid-fire and machine-guns are the means of defense. If a vessel is moving rapidly and cannot move out of the line of fire in time, her safest position to receive the torpedo is bows on, and stern on if moving slowly. With speed the bow wave would be more apt to deflect the torpedo; it should be taken slightly on one bow where the wave forms less than a right angle with the keel. Going slow, the wash from the propeller would be more apt to deflect the torpedo, and it should be taken slightly on one quarter. While heavy charges exploded in the immediate vicinity would probably explode it by concussion or deflect it, it would seem as if it were impracticable to have heavy charges ready at the appropriate places, and the chances of hand grenades being effective seem too few to warrant their presence about the deck.

The seventeenth question is: "*If your funnels be seriously damaged by projectiles, what speedily available provision can be made for the maintenance of a reasonable amount of draught?*"

This has become a more important question lately than it was when more dependence was placed on forced draught. The modern tendency to rely on increased length of funnel for draught has increased the weakness of that feature and has made the injury of the enemy's funnel an important tactical consideration. The enemy's speed might be greatly reduced by the fire of the rapid-fire guns. Small injuries might be repaired by a species of soft patch, but the heat developed at the lower part of the funnel above the armor case is usually too great, when going at high speed, to permit the use of temporary expedients, and the main reliance must be placed upon forced draught. Besides the loss of draught, the escape of smoke and cinders, at a slight elevation above the decks, might interfere seriously with battery and helm.

The eighteenth question is: "*If you decide to ram, at what speed will you steam, and how will your decision be affected by the direction in which the enemy is moving? Will you or will you not reduce speed, upon making or immediately before making contact?*"

The ship's best speed is the proper speed to make when attempting to ram, that is, not a spurt that may give out before reaching the enemy, but the highest steady speed that can be counted upon to continue during the manœuvre. Then smaller angles of helm will produce greater effect. It would be well to shut off the steam upon making contact with the enemy when striking him on or nearly on the broadside, otherwise it would be well to notice the effect of the blow before stopping the engines. You might escape with less injury after delivering the blow if the pressure was continued than if it was shut off from the engines.

The nineteenth question is: "*Having sustained serious underwater injuries to her forward part, should a ship be steamed ahead or astern in order to run her into shallow water?*"

Here again the seaman must be guided by the circumstances attending the case. If the water-tight bulkheads will stand the pressure, it is advisable to steam ahead into shallow water for several reasons. The ship can ordinarily be handled more easily when steaming ahead. Collision mats, etc., that would be put over the bow, when practicable, to lessen the leak, would be of little or no use when steaming astern, but would be held in place by the pressure when going ahead. Unless the injury at the bow had caused the draught forward to increase seriously, it would be advisable to ground the ship bows first, for otherwise on a steep-to beach the sinking of the bow might drag the ship off into deep water. The injury might be so serious as to make the bulkheads remaining unable to stand the weight of water with the additional pressure caused by steaming ahead, in spite of all possible efforts to support them; then it would be necessary to steam astern into shoal water.

The twentieth question is: "*To what extent does the principle of the isolation of heavy guns as carried out, for example, in the Royal Sovereign, Almirante Tamandare, etc., conflict with the control by the captain and by the battery-officers of the ship's gun-fire? Can any disadvantage which might arise, owing to this isolation, be neutralized by the issue beforehand of general orders?*"

The captain will only be able to have a very general control of the battery, heavy guns and light, unless it is deemed wise to indulge in broadside firing by electricity; but they will be under the charge of the officers of divisions, and the captain will give them general and special instructions for their guidance. When practicable, the heavier guns will be aimed by junior officers. The captain will inform his divisional officers of his general intentions, tell them how he proposes to carry on the action and at what range he proposes to open fire with the different calibres; in other words, will give them tactical instructions. In fleet, he should be able to designate at which opponent they are to direct their fire, and he should designate the various parts of the enemy's vessel as targets for each calibre, and see that the officers understand how to change the point aimed at according to the construction of the enemy's vessel. He must have some means of communicating with all the divisions, so as to direct them to open and cease firing, to give them the range, and when they cannot observe the fall of their shot, let them know if they are raising the sight-bar too high or dropping it too low. He must know from them when their guns are disabled.

The twenty-first question is: "*To what extent does the principle of closed water-tight compartments conflict with the communication of orders to various parts of the ship, supposing voice-tubes, wires, etc., to be dislocated or unserviceable? How is the difficulty to be provided against?*"

This will depend largely upon the construction of the ship; but any modern-built battle-ship will be in very bad circumstances when all means of communication, except by messenger, have been cut off. At some points doors must be left open, at others messages may be passed through traps in the doors; but it would be wise to have several points or centers of communication and separate lines of tubes and wires to lessen the chances of complete interruption of communication.

The twenty-second question is: "*What provision is there for the prompt removal below of wounded men, without undue interference with the continuous transport to the deck of ammunition, and with the passage of messengers, etc.?*"

This question must be answered separately for each ship according to its construction; and to provide for the care and transportation of the wounded without interfering with the service of the guns must be a matter of anxious thought. In an action of any length of time, other men will be wanted besides the usual aids to the wounded, or the guns may be left without men.

The twenty-third question is: "*Of what use to an officer, especially one employed below, is a sword? Should any officer upon going to general quarters wear a sword? Would a couple of revolvers, supplemented perhaps by a short, heavy, pointed weapon, shaped like the Roman sword, be more useful?*"

This is not a matter of great importance. Every officer should carry some symbol of authority, and a sword is one easily recognized; and some means of immediately enforcing authority should be in every officer's hands. A revolver would answer this latter purpose very well. One revolver is enough for any ordinary man to manage, and an officer would not look well weighted down with weapons. Little niceties of uniform and etiquette have much to do with the preservation of discipline without friction. The design of the sword should be such as to be suitable to all occasions, so that an officer may have it at hand always when on duty. A rapier has been suggested by some, one of medium length, as it is easily kept ready for service, is less apt to become a mere useless ornament, and at the same time is well suited to dress occasions.

The twenty-fourth question is: "*Are you prepared with any scheme whereby, even at risk to your ship, you can take on board, while underway, at least some coal, if such a proceeding is desirable? Do you habitually complete with coal in the shortest possible time, and is it desirable that when coaling you should do this?*"

No satisfactory method has yet been found for coaling at sea. The only method at all practicable in a seaway is by trains of coal-bags between the collier and the ship, one towing the other. If the collier is heavy enough the ship can be towed astern, and if an accident should happen, the greater injury will happen to the one of smaller value; besides, if the bags should dip in the sea, the wash on them will help them toward their destination, in place of being a drag. If the collier were too light it would be preferable to tow her on the quarter, using spring as well as tow line. The arrangement of the runners would depend upon the relative heights of the two vessels, and they could be rigged easily by a skillful seaman. The problem of re-coaling rapidly is almost as important as that of repairing rapidly, and countries with large fleets will have colliers with coal elevators for rapid coaling in smooth water.

Under most circumstances it would be wise to coal in the shortest time possible, and the duty should be performed with the exactness and promptitude required at a drill, for much may depend upon the rapidity with which the vessel is coaled, and the dirty work has a demoralizing tendency upon discipline and should be completed as soon as practicable.

The twenty-fifth question is: "*What are the advantages and dangers attendant upon the use of the electric search-light against an enemy? Where should a search-light, if used, be projected from? What is its effect upon the sight of your own people? What its effect upon the sight of an enemy? To what extent can the projected ray be used as a screen? Are you prepared with any better method whereby an enemy's ships or works may at night be rendered visible to your gunners?*"

The electric light permits you to search out your enemy in the dark, and at times to blind his sight, preventing officers of torpedo-boats from judging your distance correctly and the gunners of the enemy from pointing their guns. A search-light for picking up torpedo-boats should be as low as possible, but it should be in rear or to one side of your guns. The two requirements are difficult to reconcile, and positions for the lights must be selected according to the arrangements of the ship.

The light may be used improperly and dazzle the eyes of your own people or serve as a guide to show the enemy your position. It may be used as a screen by being thrown into the eyes of the enemy's gunners. It must be remembered in a fleet that you may blind friends as well as enemies, and may cause confusion by crossing the beams. Rockets and fire balls have been proposed to take the place of search-lights for illuminating an enemy's ships or works; but they are better adapted to being used from forts than from ships.

The twenty-sixth question is: *"Is any range-finder as practically useful and quick, in daylight, as a rapid-firing gun? Would you use any other in action?"*

The rapid-fire gun is the best range-finder for the larger guns if it is in the hands of an excellent marksman; but the range-finder would be most serviceable to help put the rapid-fire gun on the target, to check the gunner, and to determine the rate of change in range when the vessels are moving rapidly. The great advantage of using the rapid-fire gun as a range-finder is that for the guns you do not wish the exact range, but the apparent range. The low trajectory of modern guns makes this less necessary than formerly; still it must be taken into account that it would be a strange state of the atmosphere when there was no refraction.

Having considered the various tactical details involved in the preparation of a battle-ship for action, the next tactical problem in order is the combat of two ships. This is one of the simplest problems of battle tactics, and yet there are so many points that may arise under so many varying circumstances as to make it possible, within reasonable limits, to consider only the more prominent phases of the combat. As the gun is considered as the ruling weapon, both for offense and for defense, the object of the manœuvres will be to have as many guns as possible bearing on the enemy, to keep within fair range, to avoid unnecessary waste of ammunition, and to allow him to use as few of his guns as possible.

Two vessels meeting on approximately opposite courses, and both being ready for the combat, the first point to decide would be the time to open fire. It is pretty generally conceded that 4000 yards is the extreme opening range; for greater ranges the probabilities of hitting are too small to warrant an expenditure of ammunition when the limited supply that can be carried is remembered. Still as two ships approaching at the rate of fifteen knots each would lessen the distance by one thousand yards a minute, the time of distant firing would be too short to make early firing a serious mistake for rapid-fire guns. With heavy guns the time occupied in loading and training becomes an element of importance. At the speed mentioned, two vessels distant four thousand yards would meet in four minutes. Now, at short range the probabilities of hitting become so much greater than at long range, and where armor must be pierced the damage that can be inflicted is so much greater, that it becomes important to be able to fire at close quarters. The time elapsing between fires will differ among the heavy guns according to their calibre and mount; but it would seem safe to fire one round from about four thousand yards, and then loading at once, reserve the next round for close quarters if the vessels are drawing together rapidly. The opening range being too great to admit of piercing the heavy armor of a battle-ship, shell should be used, and the unarmored or lightly armored portions of the enemy should be the target. At close quarters a. p. projectiles would be used. Of course when firing at unarmored vessels common shell would be used at all ranges.

As the two vessels approach each other, one, if not both captains will see the advantage of employing as many guns as possible, and will use the helm to present the broadside. If the idea should enter the minds of both captains at the same time, the chances would be even as to whether they would use the same or opposite helms. When one ship has indicated her intention to sheer off the course, the other would naturally use the opposite helm, so that the ships' heads would be turned in the same general direction. Any other direction would indicate that the latter was not desirous of continuing the fight and was ready to draw off for a time, if permitted. So that naturally the vessels would tend towards each other, and when at fairly close range tend to take up parallel courses. Unless willing to enter into a ramming contest, the enemy must not be allowed to draw too close.

We may meet with an enemy who is determined to try his ram. He will endeavor to keep his ram directly on our bow. If we turn in ample time we will be able to fire more guns than he can and yet prevent him from occupying a position of advantage. Lieutenant Bethel, R. N., has pointed out the position of danger. It is having your enemy at such a distance astern that your reduced speed will permit him, by following the chord, to reach a point upon your circle at the same time you do; in other words, to ram you. This distance astern varies with the speed. While you might be able to extricate yourself from this position, it is one where you are in danger of being rammed; and usually, as bow fire is generally stronger than stern fire, he would have the advantage in guns and might damage your steering gear or your propeller.

The part of the ship towards which the attack should be directed is a point of considerable importance; it depends upon the design of the ship attacked and the relative position of the two vessels. When first opening fire the vessels will be bow on or nearly so, and from necessity the target would be limited to the forward part of the ship; but when the broadside of the enemy is exposed the target is more ample. For battle-ships the heavy guns loaded with a. p. projectiles will be used against the midship section to injure the motive power by piercing armor and striking engines or boilers; the secondary battery against unprotected or lightly protected gun crews. Smaller rapid-fire guns may be told off to injure the funnel, and by reducing the draught cut down the speed of the enemy. The small arms and machine guns will search all openings if at really close quarters. The guns in tops will pay attention to guns mounted in barbettes.

It may be found when broadsides are bearing that sufficient damage has been done already to the unarmored bow of the enemy to make it advisable to ensure considerable damage by continuing to use it as a target. The bow compartments being filled with water, the speed will be decreased by the increased resistance of the bow and the decreased immersion of the screws, and the ship will be more difficult to handle. A portion of the screws and rudder may become exposed and a well-placed shot leave the vessel an easy prey to the ram. Many of the older battle-ships have no protection for their secondary battery, and these must lose much of their power early in the combat. Some are still armed with muzzle-loading rifles for their heavy guns, and these guns would be silenced when within machine-gun range.

For cruisers the location of the battery would seem to be the most important target, for with the destruction of the guns' crews the principal sting of the cruiser would be drawn. In many cruisers there is the same danger of being raked as in the old sailing ships. At the latter part of the action, or at any time when liable to come to close quarters, it may be well to direct a certain portion of the lighter rapid-fire guns at the above-water torpedo tubes. There have been built certain cruisers that it would be wise to attack at the water-line, especially if the sea is not smooth, for they are liable to extreme lists with the admission of a comparatively small quantity of water above the protective deck. Properly protected cruisers using cellulose, cork or other water-excluding substances, and with reasonable metacentric height, should be attacked about the battery.

The object for which the engagement is fought will have some weight in determining the tactics to be pursued. The most fruitful source of single combats will be the meeting of scouts. A fleet starting out with a definite object will endeavor to cover its movements with a number of scouts, as an army does with cavalry. The opposing fleet will push out scouts to gain information. An attacking fleet without speedy cruisers loses the advantage of its mobility, as the enemy readily obtains warning of its intended movements. A fleet acting on the defensive, without an ample number of cruisers, is liable to find itself in the wrong place when its services are wanted elsewhere, and that the enemy has succeeded because his intentions have remained hidden.

Scouts must press home for news, and their main object when forced into a fight is to temporarily disable their enemy so as to avoid pursuit; whereas it is the object of the enemy to capture, disable or drive back the opposing scout. A scout after information would be instructed to avoid combats when possible. On the other hand, a covering scout will offer battle on most occasions, even risking an attack on a more powerful vessel. Therefore when scouting for information, and not seeking a decisive engagement, the hull would be the target, for with one or two of his enemy's bow compartments filled he could easily avoid pursuit. The covering cruiser would desire a decisive result, as each scout captured or thoroughly defeated is one removed from his path, one less chance of betrayal.

Should you be inferior to your enemy in battery power, and not his superior in gunnery, you would be forced to attempt ramming. It is not very difficult to draw many curves on paper representing the paths of the ships in smooth water and show how a successful ramming encounter may be conducted; but the tactical diameter, speed and handiness are so changeable under the effects of sea and wind that they can only serve as general guides and permit us to pick out the main principles to be followed. If in moving in an opposite direction you pass the enemy, turn toward his stern, not away from it. Get inside his circle if possible and keep him outside of your circle. If astern of him, and not so far away as to permit him to complete sixteen points before you reach his circle, you should be able to ram him. Inside of your enemy's circle he cannot ram you, and you may ram him. Beyond these rules all must be left to the eye and hand of the seaman. He may know all that his vessel will do in smooth water, and he may have studied the theory of ramming for years, but unless he has a quick eye, with ready decision, guided by experience, he will make a miserable failure when trying to put his theories into practice.

The consideration of a fleet in action naturally follows that of the combat between two ships. In discussing a fleet engagement it becomes necessary to consider what manœuvres are possible or advisable during the combat, and by what method the use of the weapons employed can be best developed so as to carry out the tactical maxims already mentioned, the most important being to so handle your fleet as to concentrate a superior portion of your force on an inferior portion of the enemy's force.

Admiral Colomb says: "I think you must look back to the tactics of a former age as the only foundation on which you can prepare your future tactics." Also, "The doubling now is that two or more ships should pass one ship and give her broadside after broadside or torpedo after torpedo, and thus double on her in succession and not in position."*

In regard to the possibility of attempting evolutions during an action, Admiral Boys says: "The conclusion was that there was no impediment to the gun fire from the smoke whatever, and I think ships going at that speed (8 or 9 knots), in a general action, will find very little." With a speed of from 12 to 17 knots there will be still less difficulty encountered from smoke, and to have it hang about the fleet the wind must be quite fresh and come from a direction nearly astern. It is evident that the formations to be used, and the evolutions to be performed with the necessary signals, should be as few and as simple as possible.

Assume two fleets approaching on opposite courses, A in echelon and B in line (1, Fig. 1). A turns to starboard (2, Fig. 1), in order to develop the fire of the battery and to threaten B's left flank. Should B continue on the original course, A, when

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* Journal of the Royal United Service Institution, 1886, p. 227.

clear of B's left flank (3, Fig. 1), can reform echelon, vessels turning to port (4, Fig. 1). Here it is plainly manifest that having for a time its broadside fire opposed to B's right ahead fire, A has the advantage; and as it draws towards B's left flank the fire of one after another of B's fleet is shut out by its left-hand neighbor, until all of A's fleet are opposed to the one vessel on B's left flank, and B's left flank has been doubled upon.

The disadvantage to which B is put by these manœuvres of A is so manifest that even the most rabid against tactics would hardly fail to attempt a counter-evolution, only not believing in tactics he has more than an even chance of undertaking to make the wrong move. B might attempt to develop his fire by forming column, the vessels changing course eight points to starboard (3, Fig. 2). This would be in the nature of a retreat. A would wait until B's fleet bore abaft the beam (4, Fig. 2), and then follow in chase (5, Fig. 2). A should not alter course at once, as that would give B the advantage of fire, but by following after, A can concentrate fire on B's rear vessels.

B might develop his fire by forming column, vessels turning eight points to port. Then he would have a slight advantage of fire, as A would be attacking on a diagonal; but unless B slow down, his rear would be exposed to A's fleet; and should he slow, A might charge at full speed, vessels turning four points to port; or A might slow and change direction of column so as to run parallel to B's direction.

B's best move would be to form echelon, vessels turning to port (2, Fig. 3), threatening to charge and keeping his vessels headed toward A's fleet. When near A's vessels he might form column, vessels turning to port (4, Fig. 3), thus gaining a slight advantage of fire and forcing A to change direction (4, Fig. 3). Or he might continue his course, forcing A's vessels to turn to port and receive his charge through. Should he do this, A will have had the advantage of fire up to the time of turning for the charge.

The advantage will be always in the favor of the fleet formed for battle in echelon, if correctly manœuvred against a fleet formed in line, although it will not last for a long time with vessels steaming at the rate of fifteen knots if B's fleet is also manœuvred correctly. Echelon is a formation which if vessels hold it is difficult to double upon any of them, either in succession or in position.

With B's fleet formed in column (1, Fig. 4), A would continue his course, having the right ahead fire of his six vessels opposed to the right ahead fire of B's leaders. A would turn in time, vessels turning sixteen points to the right or left, and then have the stern fire of his six vessels opposed to the right ahead fire of B's leaders. This might continue until B's leaders were disabled or until he tired of the attack under such disadvantages; and then A would assume the attack. A might decide to develop his fire at once by forming column, vessels turning to starboard (2, Fig. 4), then again to starboard, developing broadside fire, and again to starboard in retreat (4, Fig. 4). Thus always having the right ahead or right astern, and part of the time the broadside fire of his fleet opposed to the right ahead fire of B's leader.

Should B change direction to port when A formed column from echelon (3, Fig. 5), A could parallel B's direction by changing course or direction of column; or by forming echelon, vessels turning to starboard (5, Fig. 5), keep his line of fire across B's direction. B might change course to make less than a right angle with his former direction, so as to strike somewhere near the center of A's column. Should A find that B's leader was damaged seriously by the concentrated fire of his fleet, he would change direction in time so as to run parallel with B's fleet, and thus hasten the conclusion of the action, but otherwise he would prefer to turn in retreat when B's leader approached his column, so as to continue for a longer time his advantage of fire over B (5, Fig. 6).

After A has turned to starboard, B might change direction to starboard (Fig. 7). Then A might pass in parallel or nearly parallel lines his leader, changing direction when clear of B's rear (5, Fig. 7), being satisfied with a short advantage of fire over B. Or he might turn about, keeping his advantage longer, and then continuing the fight by running in parallel lines (5, Fig. 8), unless B could force a charge.

Should A be in line with B in column, the evolutions would be practically the same as above where A is in echelon. Even should A, when in line or echelon, continue his course, permitting B to charge through, B's fleet would be at a disadvantage, for the leader would be damaged and might be disabled by the fire of A's six vessels before reaching A's line, and his leader, with those immediately behind, would be in danger of being rammed, having vessels on either hand. Admiral Fremantle, speaking of an attack in line ahead (column), says: "When, for instance, should the leader be rammed, the rest of the squadron must be huddled up in a heap on top of her."*

It would seem impossible almost for the leader to escape damage and the column to escape being thrown into confusion.

It now becomes necessary to discuss what can be gained by the advantage of fire, and here as in single vessels we can first look to history as a guide. For even with the immense changes in ships and weapons since history has had to deal with sea fights, something of probable results may be gathered from its pages. Since guns were used first in sea fights, the motive power and the crew have been the principal objects of attack. Destruction of the vessels by sinking or by burning has been only incidental. The slaughter of the crews of the vessels composing the fleet has settled the result in the large majority of cases. By injury to their spars and sails their power of manœuvring was destroyed, and this permitted their more skillful or more fortunate antagonists to take up a position on bow or quarter, and bringing their broadsides to bear against a few guns, to slaughter the men on the unfortunate vessels.

The first use of iron armor was to protect the crews working the guns and the engine propelling the ships against shell fire. This only afforded the same kind of protection against the more powerful guns that the thick wooden sides did against the guns of inferior energy. In the accounts of many of the sea fights you read of the shot sticking in the sides of wooden ships as raisins in a plum pudding. In the English and French and English and Spanish naval battles, the slaughter on the French or Spanish side nearly always far exceeded that on the English side. The French ships were fought with extreme gallantry, and the men frequently stood by their guns long after defeat was inevitable. They were defeated by superior seamanship and superior gunnery. Much of the success of the English was due to the skill with which their vessels were handled, and much to the rapidity with which they worked their guns; but a part must have been due also to their superior ballistics. The English followed the custom of reserving their fire until alongside the enemy, and

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*Journal of the Royal United Service Institution, 1880.

then firing rapidly; but nothing can as well account for the far greater effect of the English fire as superior penetration that permitted such frightful slaughter.

The advent of shell guns made armor a necessity; but as protection increased the power of the gun increased, and the armor still being penetrable, the great size of the guns threatened the speedy destruction of the ship. Then the armor was taken from various parts of the ship, principally the ends, to protect the power of flotation by increased water-line protection. The motive power was placed below the water-line and thus well protected. The guns increased in size and power, and being of such great weight only a few could be carried. These were grouped together and well protected by armor. At this time not only were the guns' crews well protected, but they required few men in proportion to the size of the ship, and the places of the killed and wounded could be easily supplied; so the slaughter of the crew was not of vital importance. The fear of the loss of the vessel by sinking, growing with the size of the gun, was increased by the craze for rams and torpedoes. Great battleships were thought to be unwieldy and to be at the mercy of small rams and numerous torpedo-boats. Some common-sense and minute subdivision of the hull dissipated much of the fear of the former; electric lights, subdivision of the hull, but above all rapid-fire guns, stripped the latter of its excessive terrors. The Italians were the first to recognize that the gun was again in the ascendant, and that guns' crews must be well protected. They devoted a large portion of their armor to the protection of the battery, using subdivision of the hull, with water-excluding substances, to preserve the buoyancy of the vessel. Again the guns caused a change in the disposition of the armor, for it was found possible to use shell charged with high explosives which had an enormous shattering effect. While the heavy armor of turrets and barbettes protected the crew from direct assault, the effect of the high explosives was so great as to seriously threaten this huge structure from underneath. Not only did experiment show that they were all in danger from the force of explosion from below, but its great force threatened to blow out supports and let the structures down. About six inches of armor is considered sufficient at present to cause shells charged with high explosives to explode on the outside where they can do little or no damage.

The situation at present is this: the larger calibre of guns can penetrate, at close quarters, any armor that can be carried reasonably on a battle-ship, and but few guns of large calibre can be carried, and they require some minutes to load and fire. High explosives must be kept out and guns' crews must be protected, at least from the fire of the smaller rapid-fire and the machine guns. These circumstances have led to two principal types of armored vessels: the light armored vessels of high endurance, the real armored cruiser; and the heavy armored vessel of limited endurance, the battle-ship—both ships of the line. The finest developments of these types were outlined in the report of our Naval Policy Board, and are fairly exemplified, the first in the New York and the second in the Indiana. They are by all odds the finest vessels of their kind afloat to-day, and the present outlook is that they are types that will survive for many years, and the future improvements will be more in the line of perfection of detail than in change of design. The same parts of the vessel should be chosen as a target as indicated in the discussion of a combat between two vessels, and the admiral of a fleet should have it in his power to indicate to his ships upon what ship of the enemy they should concentrate their fire when the proper one is not evident from the situation.

A few vessels may be sunk and some may be set on fire by exploding shells; but in the battles of the future, as well as in those of the past, either before or after the motive power has suffered serious injury, the defeated ships will have retreated or surrendered because of the slaughter among the crew. It may be argued that it is more important to drive the enemy back with damaged ships than with diminished crews. But the manning of the fleets of any country will exhaust all or nearly all the trained men, and ships can be repaired, with reasonable facilities, in less time than men can be trained. Untrained men will be of but little use on modern men-of-war.

The condition of affairs has not changed the probable results so greatly as at first view would seem to be the case. Ships are much larger, and some carry very thick armor; but guns have kept pace also, and the relative value of protection and guns has not altered greatly. Increased calibre, better projectiles, improved ballistics, facility of train and rapidity in loading have kept the ratios from great changes, and the results of former combats may still serve to elucidate modern problems. Well trained men, good marksmen, on inferior ships, may serve to win the day; and with equally well designed ships and weapons, the best trained men must conquer if the ships are handled by seamen.

Should the enemy be your superior in gun power, it will be necessary to try conclusions with the ram at the earliest opportunity, provided he is a good tactician and develops his gun fire, using his superiority to the best advantage. Should he be rash enough to attack with a narrow front, you can more than equalize his superiority in gun fire by maintaining a good formation; but as soon as his manœuvres cause you to run in parallel lines you must endeavor to close and charge him. The best formation in which to charge is fleet in line.

Having the advantage in numbers, it becomes a question how to make the best use of them. The advantage may be original or it may occur during the engagement, being caused by the enemy's vessels falling out of line, because of loss of men or because of damage to the motive power. Now, superiority in speed will tell greatly, for it becomes easy to double on end or flank vessels of the enemy, and such doubling up must prove fatal to the vessels attacked. With equal speeds it will require considerable skill to develop the full value of the superior fire; but by hanging a little off the quarter astern and a little off the bows ahead, some additional guns can be brought to bear from the extra ships when in column, as also by holding a little in advance on the flanks when in line. Another way to give the full effect to the additional numbers is to pass the enemy's fleet on an opposite course, both being in column, as in Fig. 7; but this the enemy can prevent easily. In case of ramming, the full value of the extra ships may be made to tell by forming them astern of the line and having them attack after the other ships have passed through.

With two fleets of equal speed it can hardly be expected that the formations will remain intact after much damage has been inflicted, for if one fleet commander finds his ships suffering more than those of his enemy, he will seek to close and gain in the mêlée, at close quarters or with the ram, what is denied him at longer ranges for want of skill with his guns. The admiral who has gained by gun fire will be loth to sacrifice his known advantage by allowing the enemy to close; but he will find it difficult to avoid doing so, if both fleets are handled with equal skill. Again, accidents or damage will serve to disorganize the fleets, and here superior numbers can be used to advantage by filling up the gaps.

With two well handled fleets, the combat may be expected to be carried on with the ships in column and steering in nearly parallel directions, the interval gradually closing, until one threatening to charge and the other heading to meet it, the fleets come together. As they pass, some vessels may attempt to ram because of tempting opportunities, some to make up for loss of gun fire, some because they are threatened by their opposite numbers in the other fleet, and some because they believe in ramming at any and all times. Now good drill will tell. For a time the admiral will lose control of his fleet, but if his ships are well drilled and are instructed to haul out of the mêlée and form promptly, he may take a slower enemy at a disadvantage and concentrate his entire force on a portion of the enemy's unformed force. Superiority in numbers will now tell strongly. If it is sufficiently large to admit of forming a reserve, they can be sent against the enemy and strike him while in confusion. And if not held actually in reserve, they can form a second line; or if in the first line, some must be without opponents in the charge and be ready to return immediately to the fight.

The number of vessels that should constitute the line of a fleet is a mooted question. As is given in some tactical books, it is sixteen, eight forming a division and four a squadron. By some this is thought to be too large a number to form in one line. The distance being two cables, four hundred yards, the distance between the centers of the flank vessels would be six thousand yards, with sixteen vessels in line, so that the flank vessels would be too far away from the head of an attacking column to deliver an effective fire, and this difficulty would be increased with the fleet in echelon. The fleet might be manœuvred at a distance of one cable, and thus the distance apart of the flank vessels would be halved; but it is extremely doubtful whether the vessels could be manœuvred with safety in such close order during an action. When in column at half distance there would be less than a ship's length between the bow of one ship and the stern of the next ahead, and great confusion, if not disaster, would be probable if one of the vessels should be forced to stop suddenly.

Close order could be maintained readily in line, and might be an advantage when intending to charge, but it would prevent manœuvring with safety.

Eight battle-ships is a sufficient number to handle in one line, and the additional vessels should be handled separately as a semi-independent command. They could act in reserve or be used to strengthen either flank, or to extend the line should the enemy's ships overlap either flank. The fastest vessels should be held in reserve, so that they can be pushed around either flank when possible to double on a portion of the enemy's line.

Unless cruising near home ports, torpedo-boats will not be found forming a part of the fleet under ordinary circumstances. In long cruises they would serve to retard the fleet in its movements, and they would run very serious risks; but with a home fleet guarding the coasts, they would follow the fleet when not required to move too rapidly or too far for them. Then they could take refuge when the weather made it necessary. Whenever the weather permitted, and an action was probable near home, some, if not all, the harbor defense vessels would join the fleet, the proportion remaining in port depending upon circumstances.

It is well conceded that to open an attack, in daylight and in clear weather, with torpedo-boats is to invite their destruction without adequate returns. So the torpedo-boats of a fleet must remain under the shelter of the battle-ships, in a day attack, until a favorable opportunity arises for a surprise. They would be particularly useful in a charge, as coming around under the stern of one of their own ships, they could attack the bows of an enemy under the cover of the smoke that would be at its thickest at such a time, and after launching their torpedoes could seek the shelter of the same or another ship of their own fleet. Even if smokeless powder is used, the time of their exposure to fire would be very short, and the battle-ships would have to keep a very keen lookout for them.

One of the great difficulties in a mêlée will be to distinguish friend from foe, and the captain will require a cool head and a quick eye to be sure of his target when handling either battleship, cruiser or torpedo-boat, and the latter will be in danger frequently from friends as well as from enemies. They could carry distinguishing shapes in daytime. At night pre-arranged flashes from the search-light, and in fog blasts from the whistle could be used when the officer commanding the boat was certain he was approaching a friend.

To be thoroughly effective the fleet will require fast cruisers to signal the vicinity of an enemy and to collect and disseminate information. Besides the vessels attached directly to the fleet and forming part of it, many cruisers will be needed to seek out the enemy and report his movements, and to drive back the scouts of an enemy and to prevent them from gaining similar information; those attached to the fleet being thrown out as the advance and flank guards of an army, while the latter are like the scouts of an army, striving to keep in touch with the enemy and cutting off his scouts. The scouts will operate independently of the movements of the fleet, being kept informed of the points at which the fleet is to be found. The admiral will make regular rendezvous for certain times, and use his despatch vessels to keep his scouts informed of any change in the programme. The cruisers of the fleet will be sent well out on the flanks and in advance, keeping directly within signal distance or having repeating ships between the fleet and their position. The position of the cruisers in front of the fleet must be at a greater distance than that of those on the flanks, as the distance between the fleets will close so much more rapidly if the enemy is approaching on the line of advance than if he appears on the flank. If armed merchant ships are used as auxiliaries, they will be more efficient as lookout vessels for the fleet than as scouts. In the latter service they would be badly handicapped for want of protection, and would fall an easy prey to a cruiser with her engines and boiler below the water-line and with a protective deck, even if she carried a more effective battery than a cruiser.

When operating near the home coasts the cruisers will be most useful in collecting information from the signal stations, sending orders for coal and other supplies and instructions to ships separated from the fleet. A system of telegraph lines, semaphore stations, pigeon stations and lookouts, to co-operate with the fleet, is an important and necessary adjunct to all naval operations conducted in home waters and form points to be attacked by cruisers when operating on an enemy's coast. The effective value of a naval force operating in its own waters will be increased greatly by proper shore stations and telegraphic facilities. Combinations can be made with greater certainty, supplies can be obtained more readily, and an efficient watch kept upon the movements of an enemy. Where lodgments are effected on an enemy's coast for supply stations to fleets masking other fleets or blockading or preparing to bombard ports, the telegraph cable is likely to come into play; and it seems probable that a telegraphic supply ship, with its corps of signalmen, will become as necessary a part of the equipment of an attacking fleet as the flying field telegraph is of an invading army.

A fleet must have attached to it ammunition and coal vessels, unless operating near a base from which supplies can be obtained readily. A reserve supply of ammunition will be found to be as imperatively necessary on the water as it is known to be on the land. Torpedo-catchers or torpedo-gunboats become important auxiliaries when operating where the enemy may be expected to have torpedo-boats.

It is important to have the vessels attached to a fleet, both those of the line and the auxiliaries, capable of maintaining about the same speed, otherwise at important moments the fleet may be tied down to some slow vessel, or to some light vessel, swift in smooth water but unable to steam rapidly in rough weather.

All great operations with fleets must be first directed to securing or maintaining the supremacy of the sea, afterwards utilizing this supremacy. For that purpose the first object of the attacking fleet will be to seek the enemy and endeavor to crush his fleet. Should the fleets be of equal force there will be but little difficulty under ordinary circumstances in bringing about an engagement. But should one fleet be inferior it may be forced to act on the defensive, when it will strive to avoid the stronger fleet, and yet to keep so near striking distance as to prevent its enemy from attempting any considerable operation while it was at large. The superior force, if in sufficient numbers, may strive to mask the inferior one with enough vessels for the purpose, leaving the remainder to undertake some other operation of importance. If not in sufficient numbers for this purpose it must endeavor to so operate as to force its opponent into risking an engagement. Upon the number of the cruisers and the manner in which they are handled will depend largely the success of either the attack or the defense. Should the defense be better served, the weaker force might be able to neutralize the effect of superior numbers.

But should the superior force have also the larger number of cruisers it should be able to mask its own movements whilst keeping constantly informed of those of its enemy.

The formations and evolutions necessary for battle are few and simple, and therefore a complicated code of signals will be unnecessary for manœuvring a fleet in action. The following code of signals has been arranged to show how few combinations and hoists are necessary, and is not worked out as an ideal code. Of course, shapes or positions of the semaphore arms could be readily substituted for the flags. The ruling idea has been to so arrange shape and color as to make the signal easily recognized. Each ship should repeat the signal when understood, and the haul-down should be the signal of execution.

The only formations needed are column and line, the echelon being formed from line or column, the vessels being drawn up on the line of bearing in one or the other of those formations, and then turning together 45° in the desired direction.

BATTLE SIGNALS.

1. Form column on leader. White flag.
2. “ “ “ vessel indicated. White flag over distinguishing pennant.
3. Form line on leader. White pennant.
4. “ “ “ vessel indicated. White pennant over distinguishing pennant.
5. Column right, 90° turn. Blue flag.
6. “ “ 67½° “ “ “ one dip.
7. “ “ 45° “ “ “ over white.
8. “ “ 22½° “ “ “ “ “ one dip with lower flag.
9. “ left, 90° “ Red “
10. “ “ 67½° “ “ “ one dip.
11. “ “ 45° “ “ “ over white.
12. “ “ 22½° “ “ “ “ “ one dip with lower flag.
13. Vessel right, 90° “ Blue pennant.
14. “ “ 67½° “ “ “ one dip.
15. “ “ 45° “ “ “ over white.
16. “ “ 22½° “ “ “ “ “ one dip with lower flag.
17. “ left, 90° “ Red “
18. “ “ 67½° “ “ “ one dip.
19. “ “ 45° “ “ “ over white.
20. “ “ 22½° “ “ “ “ “ one dip with lower flag.
21. Open fire. Gun from flagship.
22. Concentrate fire on vessel indicated. Numeral (counting from right or leading vessel of enemy) over red and blue flags.
23. Charge. Red, white and blue flags.

Most of this essay was written before an account of the fight off the Yalu river was received in this country. Since then many reports of the fight have been published in the papers; but it is still impossible to make an accurate analysis of the evolutions performed. The Secretary of the Navy, in an article in "The North American Review" for November, has effectually demolished the outcry that by this fight battle-ships were proved to be failures. With the aid of the tables in his article, and by sifting out the probable truth from the many accounts, a fairly accurate idea may be formed of Admiral Ito's method of solving the tactical problem that confronted him on the 17th of September, 1894.

The following are the main features of the problem: The vessels of both fleets were of mixed types. The Chinese had five armored vessels. These five and one other had protection for their heavy guns. Of the four remaining, two were protected cruisers and two were gunboats. The Japanese had three armored vessels. These three, with three other vessels, had some gun protection. Of the five remaining, four were protected cruisers and one a gunboat. The displacement of the Chinese vessels ran from 7430 to 1350, aggregating 32,915 tons; and the Japanese ran from 4277 to 614, aggregating 36,462 tons. The highest nominal speed of the Chinese was 18.5, and the lowest 10.5 knots. Of the Japanese the highest was 23 and the lowest was 13 knots. The Chinese had eight 4.7" guns, seventeen 6" and twenty-five larger guns, and the Japanese had fifty-nine 4.7" guns, twenty-six 6" guns and seventeen of larger calibre. At least four of the Chinese and five of the Japanese had no place in a line of battle under ordinary circumstances. There were besides the vessels mentioned above, several Chinese gunboats and torpedo-boats that did not enter into the fight.

The Chinese were probably drawn up in double echelon, apex to the front, with the two battle-ships of 7430 tons each in the center. If they were in line or double column, the formation was so irregular as to give the appearance of double echelon.

Admiral Ito knew that the extreme speed of his enemy was ten and one-half knots, while his own extreme speed was thirteen knots while in formation, with the probabilities of at least one knot less. That the two battle-ships were his most formidable antagonists, as they were larger and better protected than any of his vessels, and could make over fifteen knots. That while the Chinese had a few more heavy guns than his vessels, they had only a few light guns and very few rapid-fire guns; whereas all the vessels of his fleet were well supplied with light guns and carried fifty-nine rapid-fire guns. He saw that with his great weight of fire properly developed he might fairly expect to crush down the fire of his enemy and damage his guns or drive his crews from them. That until the enemy's fire slackened, when he could draw closer, he could greatly lessen the danger from the slow-firing guns of the Chinese by keeping his vessels moving rapidly at a rather long range. He determined therefore to cross the line of direction of his enemy, with his fleet in column (Fig. 9), with broadsides bearing, concentrating his fire on the two battle-ships at the apex, and thus to damage them so as to prevent them from any future attempt to ram with any reasonable hopes of success. He chose the distance of about 4000 yards, so that his fleet would be able to draw well clear should the Chinese attempt to charge. He then, after passing the battle-ships and finding that they made no attempt to charge, changed direction, and drew his line past the flank of the Chinese, thus concentrating all his fleet on one or two of his enemy's vessels. After this the accounts are confusing. Admiral Ito had won the first move, and his enemy were unable to recover the advantage he gained. His fleet evidently circled around the flanks and rear of the Chinese in one or two divisions. The Chinese, while fighting bravely, were being slaughtered so rapidly as to be unable to do anything but keep up a slow fire with the heavily protected guns that remained uninjured. The Chinese drew off, followed at a distance by the Japanese. Four of the Chinese ships were sunk and one of the battle-ships was injured. Some reports say that the Ting-yuen, a battle-ship, was down by the head when the fight was over, and all agree that both battle-ships were on fire forward, which will account for their not attempting to ram. But the accounts of the killed and wounded are still more significant. Over one thousand Chinese were killed or wounded out of about four thousand men, while the Japanese lost less than three hundred, with about the same number of men.

The reports differ as to why the Japanese failed to push close after the Chinese fleet. Some say they feared the attack of the torpedo-boats after nightfall, and others that the Chinese were lost in the darkness; but it seems highly probable that after such a long engagement Admiral Ito found himself short of ammunition, and, excellent tactician that he is, he recognized the fact that the Chinese fleet was thoroughly defeated and that the strength of his ships did not warrant his attempting to destroy it by ramming. It would seem as if the only battle fought by fleets with modern weapons fully bears out the deductions drawn from the history of former battles, and that a decisive victory is to be gained by concentration of fire and concentration of ships, thus driving an enemy from his guns, rendering it impossible for him to manœuvre, and disabling his fleet by the slaughter of his men.

It is known now that the problem was solved correctly, and that Japan has been well repaid for her frequent fleet manœuvres and careful organization, and that in Admiral Ito Japan has an admiral who is both a thorough seaman and a brilliant tactician. Without an accurate knowledge of the actual injuries suffered by the fleets engaged, yet the completeness of the victory is shown by the results and illustrated by the fall of Port Arthur. The results of the victory would not have been greater had Admiral Ito seized or destroyed all the opposing fleet. He gained the command of the sea, and the fight off the Yalu river must take rank as one of the decisive battles of history.

It is evident, when considering tactical problems, that the details which are of importance are numerous, but the tactical evolutions that are required in battle are few. Yet few and simple as they appear, they are necessary and must be performed correctly. A fleet engagement may be compared to a game of chess, where various openings are possible and they admit of close study, and the correct replies may be predicted for each move. Yet a brilliant chess player, unacquainted with the openings, might be beaten by one less skillful, who, knowing them, might gain a decided advantage in the outset of the game. So with the tactician, only the early part of an engagement can be studied clearly beforehand and the correct evolutions predicted; but it is most important to open correctly, and is so easy to lose the advantage early in the combat that the best tactician may have an uphill fight if he neglect his opportunities in the outset.

Above all, the tactician must be a seaman. Strategy is a science and is capable of being reduced to fairly exact rules. It is possible to carry on its study in the closet with but little sea experience. Tactics is an art, it has only a few rules capable of many applications. Study alone will not make a good tactician; he must have a wide experience with sea-going ships under service conditions, and he must have that faculty pre-eminent in all true seamen, of quick decision, with ready observation. The tactical details so necessary to the proper conduct of a fight are only learned by careful study, after intimate knowledge of a vessel of war. Of what use is a cruiser as a scout for the fleet unless the captain is a practical seaman—one accustomed to the appearance of the various types of ships at sea? When he sees his opponent he must be able to gauge his strength and tell in what points he is superior and in what inferior to his enemy, so that he may endeavor to fight in such a manner as to develop his superior points and nullify those of his enemy. When the captain of a scout sights the enemy, if he be an experienced seaman he will be able to give definite information to his admiral, and will obtain his information more readily and run fewer risks than one who has not had his advantages.

An admiral being a seaman of experience, will grasp the indications shown by the enemy and meet his movements at once. He will select the enemy's weak point and concentrate his force upon it, and he will guard his own weak points and prevent concentration of the enemy. He will recognize when his gun fire is crushing the enemy or when his vessels are being worsted by the superior fire of the enemy. Thus he will be able to decide when to avoid a charge so as to retain his advantage, and when to charge so as to destroy his enemy's advantage, or so as to turn his first success into a complete victory.

The strategic problem may be carefully and correctly worked out, and all tactical details attended to with skill, the fleet brought in the presence of the enemy, thoroughly prepared for the fight, at the right time and in the proper place, and then, without a commander who is both a seaman and a tactician, all the finely wrought combinations fail.

There are other tactical problems, such as the tactics of the attack or of the defense of a harbor, that the limits of this essay will not permit being discussed. Many tactical details have been omitted or merely touched upon for the same reason. But the essay will have served its purpose if the writer has been able to make clear the importance of the art, its solid foundation in the history of the past and its close alliance with the art of seamanship.

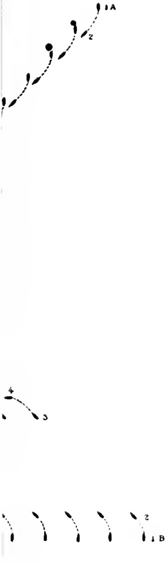


Fig. 3.

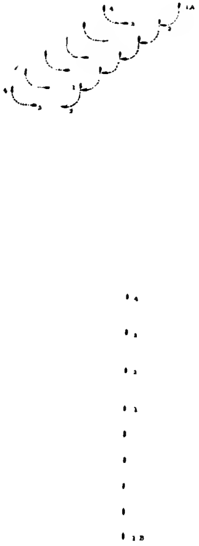


Fig. 4

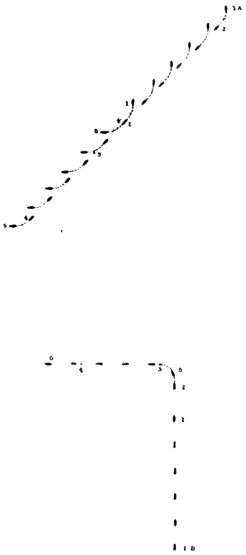


Fig. 5

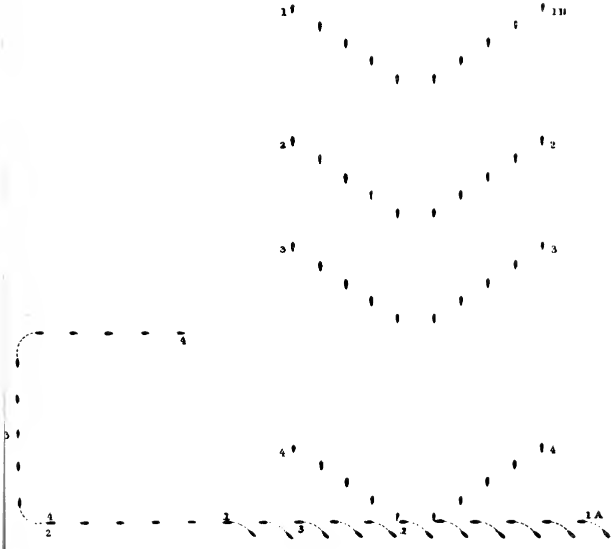


Fig. 9.

experience. Tactics is an art, it has only a few rules capable of many applications. Study alone will not make a good tactician; he must have a wide experience with sea-going ships under service conditions, and he must have that faculty pre-eminent in all true seamen, of quick decision, with ready observation. The tactical details so necessary to the proper conduct of a fight are only learned by careful study, after intimate knowledge of a vessel of war. Of what use is a cruiser as a scout for the fleet unless the captain is a practical seaman—one accustomed to the appearance of the various types of ships at sea? When he sees his opponent he must be able to gauge his strength and tell in what points he is superior and in what inferior to his enemy, so that he may endeavor to fight in such a manner as to develop his superior points and nullify those of his enemy. When the captain of a scout sights the enemy, if he be an experienced seaman he will be able to give definite information to his admiral, and will obtain his information more readily and run fewer risks than one who has not had his advantages.

An admiral being a seaman of experience, will grasp the indications shown by the enemy and meet his movements at once. He will select the enemy's weak point and concentrate his force upon it, and he will guard his own weak points and prevent concentration of the enemy. He will recognize when his gun fire is crushing the enemy or when his vessels are being worsted by the superior fire of the enemy. Thus he will be able to decide when to avoid a charge so as to retain his advantage, and when to charge so as to destroy his enemy's advantage, or so as to turn his first success into a complete victory.

The strategic problem may be carefully and correctly worked out, and all tactical details attended to with skill, the fleet brought in the presence of the enemy, thoroughly prepared for the fight, at the right time and in the proper place, and then, without a commander who is both a seaman and a tactician, all the finely wrought combinations fail.

There are other tactical problems, such as the tactics of the attack or of the defense of a harbor, that the limits of this essay will not permit being discussed. Many tactical details have been omitted or merely touched upon for the same reason. But the essay will have served its purpose if the writer has been able to make clear the importance of the art, its solid foundation in the history of the past and its close alliance with the art of seamanship.

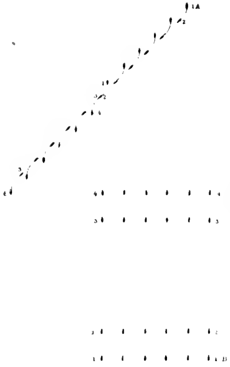


Fig. 1

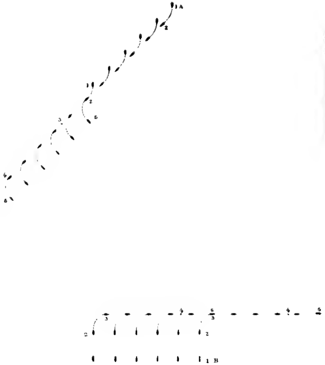


Fig. 2.

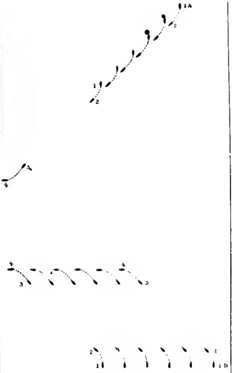


Fig 3

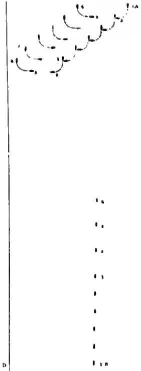


Fig. 4

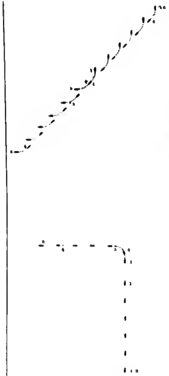


Fig 5

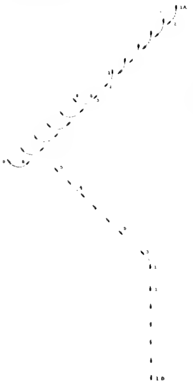


Fig 6

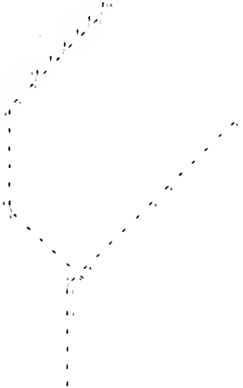


Fig 7

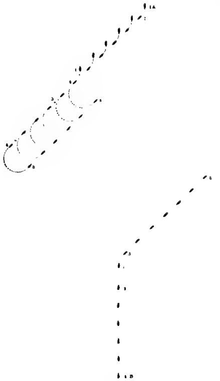


Fig 8

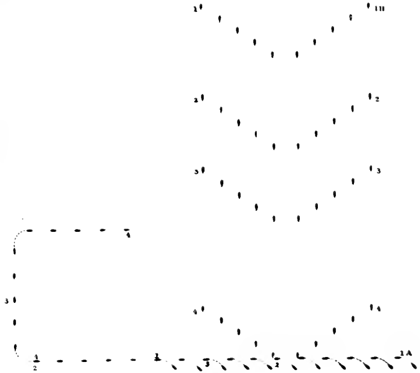


Fig. 9.

DISCUSSION.

Commander C. F. **Goodrich**, U. S. N.—This essay is an admirable example of what our Institute is capable of bringing out, and I am in agreement with the Board of Control that it well merits the distinction awarded it. There are many points wherein a difference of opinion may lie, but as a whole I think the members have cause for self-congratulation on its publication.

I confess to a wish that the elements in the fleet had been discussed at greater length, for they are yet ill-defined in my own mind. I had especially looked for light on the subject of the armored cruiser, a type whose exact place and functions are not clear to me. I grant its excellent qualities and I speak of the New York with just pride; but in time of war what shall be her rôle? I can understand the battle-ship and I can understand the cruiser. Their prototypes were the 74-gun ship and the frigate. The gradual settling down to one standard unit in, and the elimination of the frigate from, the line of battle is well shown by Admiral Colomb. What new necessity has arisen for the bewildering heterogeneity of the modern navies of the world? The writer carries hope to many hearts in recording "a tendency to settle down to fewer types of vessels." Yet without this tendency crystallized into rigid practice the handling of his supposed fleets will be difficult beyond measure. What *can* be done with a squadron of vessels all or nearly all of which vary in size, speed and tactical qualities?

I have limited my remarks to the point on which I need most enlightenment and which, it appears to me, might have been longer dwelt upon profitably. As a whole, this essay, written in a capable and conservative manner, seems exceptionally free from attack.

Lieutenant-Commander **Seaton Schroeder**, U. S. N.—The prize essay of this year is a comprehensive and masterly discussion of the elements necessary to naval victory. While the commander of a fleet should not have his mind burdened with details, distracting in more senses than one, it is to be observed that the successful commander is he who appreciates the value of details and who can, without direct personal supervision, ensure the perfection of his fleet in these minor essentials. A consideration, therefore, of the details involved in arming and preparing a ship for action seems eminently appropriate in a paper such as the one under discussion.

A most important question is raised in the early part of the essay as to the kind of gun best adapted for cruisers, and the suggestion that for them it would seem better to decrease the length and increase the caliber is both interesting and wise. Until comparatively recently there were many advocates of the principle of mounting a few large heavy guns in small vessels as opposed to a greater number of smaller guns. These advocates could not stand up long before the inexorable logic of facts, and the same revulsion that is always created in such cases, apparently, carried popular opinion rather too far the other way, being helped on by the extension of the application of rapid-fire mechanism to 4-inch and 5-inch guns. It is strange that in the proposal to put large guns in unarmored vessels it has always seemed to be taken for granted that they should be heavy and high-powered. Why not keep a large caliber as proposed, but decrease the weight and power? A 9-inch gun weighing 12,000 pounds, or about the same as a H. P. 6-inch, would throw a most destructive shell with an I. V. ample for all needs of a cruiser. It would not go through heavy armor; but cruisers are not intended to fight heavily armored vessels; and even if caught by one such, a vast amount of damage could be done, and the explosion of such heavy bursters might well give a chance to escape before being totally wrecked. The higher trajectory would make long range firing more dependent upon an accurate ascertainment of the range than if the battery were H. P. 6-inch; but if the vessel armed as proposed keeps pointed at full speed for the enemy it will be almost impossible for the latter to prevent the action taking place at 1500 yards or less. Of course heavy, long-range guns should be installed for end-on fire in either direction, and the broadside 9-inch guns would be fitted to use metallic case ammunition to secure rapidity of fire. Other things being equal, in a duel at a range not exceeding 1500 yards, one ship having a broadside battery of H. P. 6-inch guns and the other the same number and weight of low-powered 9-inch, there should be no doubt as to the result. As expressed by the essayist, "The cruiser throwing the larger shell would be more powerful than the one armed as at present."

In the study of the individual ship, means of internal communication under varying phases of disablement are of primary importance, and the solution of the problem comprises not only the best and most ample independent lines of voice tubes and telephones, but even still more necessarily the installation of guns, torpedoes, steering engines, dynamo rooms, magazines, etc., in such wise as to reduce to a minimum the number of such necessary lines. Every instance of the power to give an order *viva voce*, instead of by tube or messenger, is a distinct gain in efficiency. For all such questions bearing upon the efficient handling of the battery (which is the one object for which naval vessels are built) it would be well if the Chicago could be paraded as an object-lesson before the navy.

The 7th question, regarding the provision for making signals, is well answered by the essayist, and too much weight cannot be attached to his statement that "protection must be provided for the signalmen." In all vessels a certain amount of signaling is likely, but in a flag-ship there will necessarily be much more and it will be more vital. And yet when we hear that such and such a vessel is to be changed into a flag-ship the alterations do not generally go much further than to cut the captain's quarters in two so that he and the admiral shall have separate places to eat and sleep. I do not remember hearing of any of our vessels thus transformed being provided with a military shelter for the commander-in-chief nor for the signal officers or men. Yet what is more important? Machine guns, as at present constituted, would annihilate all these people at a considerable range. There should be a tower for them, impervious to secondary battery fire, either immediately over or in intimate communication with that of the captain. This will add weight, of course, and the weight will be high up, but it is an absolute necessity; if that be recognized it will remain to be decided which type of ship is best for the admiral to be in, to fit up no more of those than necessary and to make the towers as small as compatible with convenience. It would seem that the necessarily restricted size of this tower constitutes in itself a valid argument against the adoption of a signal code requiring as many flags as does a letters code, which is sometimes advocated in place of one using numerals.

While I agree that there is danger in carrying live torpedoes in above-water tubes in action, I think I would have them prepared if close action appeared probable, for the chances of the little 35-grain fuze being hit are small, and the charge itself if hit should not detonate. The air flask is a source of danger, of course, but there are torpedoes that have other means of propulsion. I am referring to broadside tubes. I cannot imagine any one leaving a torpedo in a bow tube of a ship.

The hint regarding the escape of gas from explosions between decks brings us right against the time-honored custom of battening down all hatches that can be spared. What object can be gained by that practice nowadays, or what harm will result from leaving them all open, is hard to see. The exploit of the gallant topman dropping a grenade from the Bon Homme Richard's yard-arm down the hatch of the Serapis and killing and wounding sixty-odd men will not be repeated in these days.

The recommendations, in answer to the 13th question, that there should be several protected stations from which the captain could fight his ship, and that the conning tower should be of easy access and communication from the deck, will undoubtedly find a universally favorable echo. Before the importance of the matter was realized, instances were known of the route from the tower to the deck being made long and circuitous and of there being no way of communicating from the deck with the men at the conn. Such a mess simply invites disaster. There is hardly anything more important than perfect freedom of movement for the captain; he should be able to leave the tower and gain the deck at any instant, handle his ship perfectly from outside and jump in again at a moment's notice. All such terrible mistakes will probably be corrected and certainly will not be repeated; professional voices should be raised in protest, if necessary, against such a handicap.

The problem of ramming or being rammed is indeed not one of simple diagrammatic solution, and the principals in a duel will do well to remember that distances will not be as accurately estimated as on the drill ground, and furthermore that the curves described will not always be the same; difference in trim, relative force and direction of wind and sea, difference in the relative speeds of wing screws, variations in the times required to stop or reverse the inner screw and, most of all, the uncertainty as to what the other ship will do,—these all combine to take it out of the category of an exact science. A quick eye and hand skilled in sea-craft, and a cool brain comfortably stocked with sound judgment and practical sea experience, are the instruments with which one may save that vital "half-length."

The discussion of the formations in which to fight a fleet carries with it doubled weight and interest as coming from an officer known to have given so much thought to the subject. A salient feature of the position taken is approval of the echelon formation; and the fact, as stated, that it is a difficult one to double upon certainly imbues it with important tactical strength. It is difficult to work out by diagrams the innumerable problems arising from the many bearings on which the enemy may appear. The essayist has fully considered the cases in which he bears ahead from your echelon, and, if desired, that situation could generally be brought about. With him bearing at right angles to your line-of-bearing, the echelon formation will continue to present certain advantages, prominent among which is that of bringing to bear the greatest number of guns while presenting the smallest target, and that I take to be a cardinal principle. It also places the water-line and battery armor at an angle with the line of fire. It is assumed, of course, that all the broadside guns can be trained well forward and aft of the 4-point bearings; no vessel not thus arranged has a proper right in the line of battle; vessels with turrets placed diagonally carry the stigma of vital defect in their inability to concentrate the fire from both turrets on either bow and quarter.

Being in echelon, on a line-of-bearing perpendicular to the direction of the enemy, if he advances in line you will gain sea towards his flank, and, to prevent concentration of your fire on that flank, he may form column, turning in that direction and bring his broadside to bear. You will now be giving him gun for gun, while maintaining the most favorable angle of presentment. If some of your battery should become disabled a simultaneous turn of eight points towards him would put you in echelon with the other flank forward and a fresh battery in action, and you would draw toward his rear. If the relative marksmanship or gunnery power of the two fleets be such that these conditions are favorable to you, the condition should be maintained as long as possible, being prolonged possibly by reducing speed or possibly, if not too near, by changing course again eight or sixteen points and steering in retreat in echelon. The propriety of manœuvring in this way will depend a good deal upon the distance of the enemy. To change formation in his face might easily be a fatal error, and even changing front should be well considered; moreover, the time taken up would be practically lost to the guns, as the snap shots taken while turning with full helm would probably not be very effective.

A valid reproach to the echelon formation is that it is not elastic and that before entering another formation the squadron has to form line or column. Another disadvantage is that the distance between vessels is sometimes thrown out by entering it and sometimes on leaving it.

But if these peculiarities are kept in mind and looked out for, great advantages may attend its employment. While manœuvring as suggested above, if the enemy makes up his mind to close you cannot well stop it; but up to the last safe moment you will have the advantage by keeping in echelon, and when the shock of the charge comes you should be in better shape than he.

I agree with the essayist that sixteen modern vessels is an unwieldy number for the line of battle. If in line or column, even with the commander-in-chief in the center, there could be little or no signaling, and, in line particularly, bearing and distance could not be well kept. While there should be as little signaling as possible after the action has become imminent, some will be necessary if only to indicate that a previously arranged 1st, 2d or 3d plan of action is to be followed; and smoke from guns and funnels will make that difficult enough without the additional perplexity of distance.

Half-distance is too close for battle. I have seen our own and a certain foreign squadron at drill at half-distance; and Admiral Walker's full squadron of eight going through Hellgate at half-distance, 10 knots, was a handsome sight and a fine object-lesson. But on all such occasions there is no shooting going on and no smoke, and, moreover, all the best compensated compasses are in place and various more or less useful implements for verifying bearing and distance are conveniently installed. In action there will be little more than the one, possibly sluggish, compass in the tower, a more or less restricted field of view, an undoubtedly greater tension on the nerves, smoke, roar, confusion, the distraction of looking out for torpedo-boats, anxiety regarding the signals, possibility of loss of control for a short but vital space of time (through disablement of steering gear or steering men), etc., etc. In line, which in some respects is safer than column, although more difficult, that thing about compasses is most serious. The echelon formation comes again to the front in this connection; the principal danger would be that when enveloped in smoke one vessel might forge ahead into the line of fire of her leader, or drop astern and endanger her follower in the same way; but that would not be as serious as the possibility of ramming the leader in column or coming together in line.

Eight, therefore, appears to be about as many vessels as should ordinarily be in one line or column. If more are present a compound formation could be adopted and the second squadron would have to be more or less independent, as suggested by the essayist; that is to say, independent of all except general instructions to protect either menaced flank, concentrate on some one part of the enemy, etc. The first squadron being at "distance" apart, the other, whether the formation of each be line or column or echelon, could keep close enough on the off-side to form an effective indented line, column or echelon; that is to say, to have their guns bearing through the intervals. In case of a charge through, should the enemy receive the attack in column, the rear line should range up on this side of him with the same helm as the van and thus double on him in position; should he receive it in line, the rear ships should get astern of their leaders in the van line by the time the fleets got together, and possibly by previous signal try to ram the enemy's ships as they come through. Torpedo boats and their antidote, the "hunters," would have an influence in individual cases in modifying the decision as to what precise course to pursue; but the relative positions of squadrons just indicated appear to be the best calculated to develop to the utmost the gun power of the whole fleet, torpedo-boats or no torpedo-boats.

The closing paragraph of the essay is the enunciation of a sound maxim. The naval administration which fully realizes the importance of the art of naval tactics and its close alliance with the art of seamanship will, in war, find itself well repaid for expenses incurred in the preparation of officers and men. A seaman admiral is needed to handle a fleet, a seaman captain to handle the ship and a seaman gunner to handle the gun. In a broadened sense, "the man behind the gun" will decide the day.

Lieutenant J. F. MEIGS, U. S. N.—I have read Lieutenant-Commander Wainwright's article on "Tactical Problems in Naval Warfare" and have been much interested in it. Mr. Wainwright has given us a very good historical resumé of the progress of change in naval equipment and warfare. I say change, and not improvement, advisedly, for I am by no means sure that all the changes which we have witnessed in the last 30 years have been improvements. The people occupied in developing guns and torpedoes, steam engines and ships have run away with the naval officers and have produced wonderful results, but in many cases have failed to secure a proper balance of various elements. We have far too much complication in almost all respects. In my view the whole kernel of the gun question now is to be found in its breech mechanism and gas check and in the size of its bore. In other words, all other details of the modern gun are so well worked out and so nearly similar as to be devoid of interest. I question whether present guns can be operated rapidly, because of difficulties in opening the breech, and I also question whether the present strife for higher velocities, which means necessarily long guns and large powder chambers, is well advised. If ships will engage at distances less than 1000 yards from each other, as I believe will be the case, it is of small consequence what a gun will do outside of that range; and if the whole of the trajectory of the gun for 1000 yards is dangerous space, then the two elements which give flatness of trajectory—high velocity and what is called sectional density or length of shot—are sufficiently developed.

It appears to me that the respect in which needed advance has been most lost sight of is in slowness in ammunition supply. The means of supplying ammunition are not materially better than they were 50 years ago and are perhaps absolutely slower. Yet we have added numerous devices which should enable guns to be fired at much greater speed than was the case 50 years ago. My own view is that the general estimate put upon this increased celerity of fire is far too high; but there is an increased celerity of fire without a parallel increase in the facility of supplying ammunition.

Very interesting are the tactical questions of the proportion of hits which will be obtained at given ranges and the closely allied question of the determination of range. Inside of the danger space the determination of the range is unnecessary, and this is the principal reason for high velocity in projectiles. The proportion of hits which we will get to-day is not, I think, materially greater than what would have been got with the old guns, if both be operated within their danger spaces. The new gun is a more accurate instrument than the old one; but the gun is so much more accurate than the men who use it that the accuracy of the man and gun taken together has not materially changed. Nor are our methods for determining range, which becomes of consequence outside of the danger spaces, better than they were formerly. The effect and result of this is that it will be of no value to fire guns outside of their danger spaces. In other words, ships must, as they always have done, fight within the danger spaces, and though we should no doubt have the best range-finding apparatus which can be had, still because guns cannot hit often beyond their danger spaces, and because the best range-finding apparatus is inaccurate and clumsy, we must recognize the fact that guns will not be used much where range-finding is necessary. If all these things be true, numerous important tactical results follow. The range, which is the element of naval combat about which we are most uncertain, becomes fixed.

The most interesting question in gun tactics is concerned with the fixing of the caliber of a gun. Should we have in each battle-ship 13-inch guns, of 30 calibers length, weighing 60 tons, and throwing projectiles of 1100 pounds weight, or should we have 16-inch guns, of the same weight, of less length, and projectiles of the same length but necessarily of greater weight, or guns of 13-inch bore but of lighter weight than the present 13-inch? Such is one of the questions now pressing for decision. The whole world, following this country, has within the last three years adopted face-hardened armor. Such armor can be destroyed by weight of shot. It can be destroyed also, it is true, by comparatively light shot moving at high velocities; but having in view the introduction of face-hardened armor, are guns of the present right, or should they become shorter and have larger bores, heavier projectiles and lower velocities? But though the velocities become less, yet if these velocities, having in consideration the increased weight of shot, are sufficient to retain unchanged the form of the trajectory of the shot in the first 1000 yards of its flight, then for the purpose of hitting or for purposes of war the use of the larger bore gun with the same weight will cause no loss whatever. It will cause many gains which it is not necessary here to enumerate and will, as I say, cause no loss. Again, the use of larger bores and lower "power," to use the term generally employed, would carry us back to the use of smaller and lighter charges. In other words, would enable us to increase the ammunition-supply of ships, which has now, as we all know, reached an extremely low point. We used in former days, in direct fire, charges as low as 1-9th or 1-10th of the weight of the projectile. This would result, as compared with the present practice of loading guns, in ships carrying five times as many charges as now without alteration of their magazines. Even if the charges were reduced to ¼ or ⅓ a material gain would be effected, or we should gain all that we hope to gain in ammunition supply by using smokeless powder.

Such questions could be multiplied indefinitely and are of the highest interest and importance. And if these be not solved, and solved correctly by naval officers, they will remain without solution. I therefore hope that Mr. Wainwright's paper may meet with a full discussion and may lead to the elucidation of the numerous points dealt with. I have no criticisms to make as such on the views which he expresses. I have no doubts in my own mind that the gun is and will remain, as he appears to admit, the principal weapon in naval warfare. Ships should, however, not be without rams and the mobility which will enable them to use these. Of the torpedo I do not feel so sure. It is extremely complicated, and it appears to me that its use anywhere but well below the water-line is most perilous.

In regard to armor: As ships stand to-day ordinary unarmored cruisers with the guns of their main batteries can penetrate their twins anywhere, even if their tops are below the horizon; that is, at ranges enormously greater than those at which they can hope to hit. One hundred years ago frigates could not penetrate their likes outside of about 1000 yards. Similarly to-day battle-ships without face-hardened armor can usually penetrate the heaviest armor of ships of the same class at about 2000 yards range, that is, at ranges where they can rarely hit; whereas in former times battle-ships could penetrate their likes at ranges of about 1000 yards or just beyond the then existing dangerous space. And unless the men who are to fight the ships to-day have steadier nerves than those of former times, the strain thrown upon them is perhaps injudicious.

Prof. P. R. ALGER, U. S. N.—Referring to Mr. Clowes' first question and the lecturer's answer, I think it should be pointed out that we pay too little attention to designing the internal fittings of our ships of war for war purposes. Ships should be cleared for action, as far as practicable, by their designers. We cut our decks up too much with unnecessary bulkheads; build too many staterooms and offices; have too much furniture and too many movable ladders, stanchions and canopies. Every bulkhead not actually needed for structural purposes should be removed from the gun decks, and all wooden sheathing, ladders and hatch combings should be abolished, so that the fighting decks are always as clear, fore and aft, as they can be.

As regards the lecturer's idea of designating various parts of an enemy's ship to be attacked by the different classes of guns, it needs but a glance at the accompanying sketch to show the impracticability of such a scheme. This sketch, if held fifteen inches from the eye, rep-

resents the Indiana as she would appear at 2000 yards range, only with much sharper outlines than would be the case in reality. To attain the best results *all* guns should be pointed at the middle of the enemy's ship except at *very* close range.

Lieutenant A. P. NIBLACK, U. S. N.—The questions dealt with by Lieutenant-Commander Wainwright are so much to the point that whether or not his solutions are entirely satisfactory is of less importance than that a great body of progressive officers, line and staff, should be reminded that there are such questions in the naval profession. Unfortunately we need these reminders, for they are not such live issues with us as with some other navies. To be sure, our ships are noted for their smart appearance, their double bottoms are inspected with the greatest frequency, and the numerous returns and blank forms are, in the main, very creditably filled out. Everywhere the new navy makes a good impression, and in the cuts and pictures in the newspapers and periodicals the new ships lose none of their impressiveness. But in the matter of systematic target practice, of turning circles, fleet manœuvres, torpedo drill, the school of the ship, the school of the section and the things which count for battle efficiency, our experience as a body of officers is remarkably limited. This is, however, not the fault of naval authority. Our few cruisers have been entirely absorbed in police duty for the State Department and in watching various political upheavals in remote parts of the world. We can only hope for a squadron of evolution when we get battle-ships which cannot be sent off on telegraphic notice to Kamschatka or Zanzibar, and only hope for good work out of the squadron when it goes off to some secluded body of water, for two or three months at a time, to escape the distractions from the inevitable visitors. Two ships fervently employed in the school of the ship and the school of the section for two months can give more valuable experience to the people on board than can be gained by a conventional three years cruise on any station as now conducted.

Our principal data for solving tactical problems we must glean from foreign periodicals, for our familiarity as workmen with our own tools is largely theoretical.

The following are some of the points very well worth noting in the essay under consideration:

"It is evident, when considering tactical problems, that the details which are of importance are numerous, but the tactical evolutions that are required in battle are few." Our Fleet Drill Book needs revision along these lines.

"The object of the manœuvres will be to have as many guns as possible bearing on the enemy, to keep within fair range, to avoid unnecessary waste of ammunition, and to allow him to use as few of his guns as possible." If it were added also, "To keep the weather gauge," then this would fairly state the problem of battle tactics.

"When the captain is on deck the executive should be in the conning tower, and if the captain is in the conning tower the executive should be on deck under some protection. . . . There should be several protected stations, at least one on each bow, from which the captain could fight his ship (but connected with the conning tower as to signals). . . . When piloting is necessary the navigator must be at or near the wheel to conn the ship and keep her from running aground, as the captain would probably need all his faculties to fight his ship properly. . . . The senior watch (ordnance officer) should not be called from his duties, unless required to take the position of the executive.

"The tendency is to settle down to fewer types of vessels. . . . The finest development of these types (armored cruisers and battle-ships) . . . are exemplified, the first in the New York and the second in the Indiana. They are by all odds the finest vessels of their kind afloat to-day, and the present outlook is that they are types that will survive for many years, and the future improvements will be more in the line of perfection of detail than in change of design."

The belted or armored cruisers "are fit, usually, to take their place in the line of battle, and are battle-ships of great coal endurance with comparatively light armor." This is rather heretical, but certainly the Brooklyn need ask no odds in the line of battle. Unless we get more ships than are planned we will not have any line of battle.

As regards what the essayist says of "Clearing Ship for Action," I think a clearer view may be had of the question by considering that its object is: 1st, removing obstructions from the working of the battery inboard and clearing the arc of each gun's fire outboard; 2d, removing splinter and missile-producing objects from the vicinity of each gun and chain of ammunition supply; 3d, taking all precautions to prevent wreckage from fouling the screws; and, 4th, improvising protection to exposed men (signalmen, sharpshooters and helmsmen), to torpedoes and their gear, and supplementing, as far as possible, the ship's protection to its vital parts. In time of war the ship would always be as nearly ready as practicable, and on going into action as much would be done as possible in the time allowed. The unbending of chains is of doubtful expediency. If, in ramming, they should drop aboard the enemy, by veering and letting go the bitter end you might be able to present him with that much additional weight to help him down. The ability to let go anchors on soundings to spring a battery, if disabled in engines; or with a ship dangerously down by the head from being pierced forward, the ability to let go anchors and chains quickly to relieve her; or in case of an anchor being knocked off the bows from any cause the chain would hold it,—these considerations give us the choice of bending or unbending according to the chances. With a disabled crew and a ship well battered up there would be enough work to do after or during an engagement to make bending chains quite an unwelcome task. The danger from having chains bent is reduced to a very small margin if the stoppers and bitter ends are accessible for cutting or slipping quickly.

The question of steering the ship by the bridge wheel or that in the conning tower is one worth considering. As long as the danger is not too great the bridge offers every advantage, but the helmsmen should be protected by hammocks. The protection to signalmen is almost impossible except such as hammocks afford.

The question of the danger of the war-heads of the Howell or Whitehead torpedoes being detonated by a chance shot might be settled within all reasonable limits and very inexpensively at the ordnance proving-grounds by a series of experiments on models. There is no question as to the danger from the Whitehead reservoir being pierced, but I think the other danger is seriously exaggerated. Using under-water tubes reduces this to a minimum, but these have certain disadvantages.

In the question of interior communication we strike great difficulties. Speaking or voice-tubes are a failure and they weigh inordinately. The telephone is the best substitute, because any danger from interrupted communication owing to the wires being cut in action can be overcome by running wires over all as in the army field telephone service. This device consists of a reel of wire and two small telephones. For use on shore the wire is several miles long, but on board ship a number of sets of telephones with shorter wire should be kept in the conning tower in action to run to parts of the ship to where the regular communication has been cut off. This is by far the best solution of the problem.

One excellent means of getting the range of an enemy, if the height of his masts is known, is by means of the Fiske Stadimeter. Each divisional officer should have one and determine his own distance for himself when they fail to inform him from the bridge or conning tower. If the heights of the masts are not known they can be gotten approximately as follows: Get accurately the distance of the ship by means of a range-finder; set the stadimeter at that distance and bring the images in contact by means of the tangent screw. The height can be read off the scale. Two or three approximations will give it pretty nearly.

Signaling in battle offers many difficulties. In time of peace it is not an easy matter to communicate under certain circumstances. At night we have ample means of communicating, but in the daytime flags are very unsatisfactory. The smoke of battle at times corresponds to the conditions of a fog. In our ships steam whistles are, as a rule, badly placed for signaling. The best solution of the signaling question is to put large military armored masts in all vessels that can stand them and use them for signal towers. The base of the mast should, in the flag-ship, be an armored compartment for the admiral and his staff. Some of the signalmen would be in the tops. A steam pipe should be run up the mast to a whistle for signaling purposes in the top. A cone reflector should be used with it to throw the sound in any special direction. Certain battle signals in the daytime would be made with Very's stars and rockets. If the halliards are shot away battle signals with flags could be made from the tops by bending the desired flag (if only a one-flag signal) on a staff and waving it from the top till answered. A jack-staff in the top would enable two-flag hoists to be made.

The essayist gives a battle code of signals which is only intended "to show how few combinations and hoists are necessary, and is not worked out as an ideal code. . . . The ruling idea has been to so arrange shape and color as to make the signal easily recognized. Each ship should repeat the signal when understood, and the haul down should be the signal of execution."

I am inclined to think that whether there is an official "battle code" or not commanders-in-chief will invent codes of their own before going into battle. It is trusting too much to the chances of our code being known to the enemy if published in a signal-book. Lieutenant-Commander Wainwright's code might therefore be as good as any other if it did not involve the really vicious principle of dipping flags to indicate certain meanings. It seems to me that the logical way to make the 23 signals he gives is to make them by regular code with the regular flags, and at the same time I don't think his 23 signals cover the case. The repeating back of signals is an excellent thing. A signal might be shot away when hoisted and before answered by all the ships. The hauling down of a signal is of course the signal of execution, but tactically or otherwise a vessel should never put her helm over without indicating it to her consorts by her whistle. It is always an additional check on the signal being understood.

The essayist says also, "The only formations needed are column and line, the echelon being formed from line or column, the vessels being drawn up in the line of bearing in one or the other of those formations and then turning together 45 degrees in the desired direction." On this text an essay might be written. We have in our tactics now a mixture of the direct and the rectangular movements. I should be glad to see all the direct movements stricken out except such as are indispensable (there are several). I think that echelon is best made from line or column on a line of bearing. If vessels are in line at distance (400 yards), and echelon is formed by the direct method to the front, there is a general change of speed, and when the vessels are in echelon the oblique distance between them is 566 yards. If column is now formed by a half turn the distance is 566 yards instead of 400 yards and there must be a general closing up. In changing formations direct methods unduly increase the chances of collision and require more care and judgment in their execution.

In the manœuvres of the fleets A and B in the tactical illustrations in the essay, I don't think the author emphasizes enough the advantage of getting and keeping the weather gauge where there is a choice in flank movements.

However, any one must be very ill-natured indeed who will quarrel with Lieutenant-Commander Wainwright on his excellent essay, and I, for one, am very much indebted to him.

Lieutenant J. H. GLENNON, U. S. N.—In regard to the echelon formation which the prize essayist advocates it may be remarked that, referring to Fig. 1, the vessels of the B fleet should, at extreme fighting range or near there, left turn. The vessels of the A fleet would then be compelled to turn to the right. In case they do not, but half turn or keep straight to the front, the B vessels, before or when the leader arrives on the line of bearing of the A vessels, should change simultaneously to the heading of the A vessels, after which, unless A changes his formation, the signal might be made to B vessels to follow the movements of the enemy as to speed and direction.

First, supposing that A, when B's vessels left turn, turns so as to run parallel with B. If we draw lines from all of B's vessels to A's nearest vessels and then operate similarly with A's vessels we will see that the average range from B's vessels to any of the nearer vessels of A is less than that from A's vessels to the nearest of B's, though with the vessels farthest off the opposite is the case. Now, the object in a gun attack is to get more of your vessels within fighting range of some part of the enemy than he can get on any point of you, and therefore I believe that B has the advantage of position. In short, A in advancing in echelon, leading vessel in front of any part B, is really presenting his flank, and B should simply endeavor by running away, turning or changing his formation if A does, to hold on to that flank. All this is not said in any spirit of criticism, but is supplementary, if I may so put it, to what the author has written. He has not, I think, sufficiently considered the possibility of B's running away; B might go slow in the latter case, as he will lose nothing by close quarters, but will have the advantage both in guns and torpedoes, and with sea-room he will have absolutely nothing to fear from the ram.

All must admire the author's courage in presenting a consistent scheme of battle tactics and his wonderful fertility of resource in handling the questions put to the Institute by Mr. W. Laird Clowes.

There is one thing in battle that may frequently be of prime importance, and that is "interference," the interference of the Chen Yuen between the Ting Yuen, which was on fire, and the Japanese fleet at the Yalu for example. The King Yuen might possibly have been saved in the same way. Vessels will frequently become powerless through fire, and may be from sudden large loss of their fighting force and in other emergencies. A signal in time to a friend to keep between you and the enemy may often save your ship and the battle. In closing I may say that the group formation and battle, something similar to the present skirmish drill for infantry, has points well worthy of notice. The field is the sea, the perfect level to which this species of fighting is particularly applicable.

W. LAIRD CLOWES.—I greatly regret that time will not now permit me to discuss at any length the Prize Essay which has been sent in by Lieutenant-Commander Richard Wainwright, U. S. N., whom I heartily congratulate upon his deserved success. He has, I venture to think, admirably distinguished the limitations of the teachings of the past. These are, I fear, too often lost sight of. I have myself noticed in recent controversies in which I have been engaged a tendency on the part of my opponents to hurl Nelson and Hawke at me on much too slight provocation. It ought, surely, to be our endeavor rather to try to imagine what the great commanders of old times would now do were they in our position with our matériel, than to seek slavishly to adapt our matériel to their tactical principles. In this respect Admiral Ito, at Hai-yun-Tau, seems to have hit the happy mean. He adapted the principles utilized by Nelson at the Nile and at Trafalgar—the principle, I mean in particular, of doubling on and crushing a part of the enemy's line as a preliminary operation—to modern conditions. That such a system of attack ought, if possible, to be still applied has been the opinion of all our recent British tactical writers; but I do not know that one of them has succeeded in laying down any set of rules whereby the end in view may be attained. Nor, I suspect, are any rules on the subject now capable of the broad kind of application which attached to similar rules in the days of sailing ships. Conditions are now so much more variable and diverse than they used to be. In the rapid improvisation of adequate methods lies the true genius of a naval tactician; and although a few old base principles remain unalterable, we must depend daily more and more than we did upon the cool head, the originality and the instant decision of a commander-in-chief, and less and less upon mere traditional modes.

The essayist, while giving full value to the gun as a tactical weapon, allows, I think, too much value to the ram and far too little to the torpedo. I regard the career of the ram as ended. The fear of the torpedo and the terrible effect of heavy-gun fire at short range are factors which cannot but tell for many years to come and which must inevitably render close action, in the old sense of the words, between large modern vessels very infrequent, even when one party has a superiority of speed sufficient to enable him to select his distance. But effective action cannot be maintained at much greater range than 4000 yards, and at that distance, even in daylight, torpedo-boats, lurking under the lee of the big craft, have, I am fairly convinced, splendid chances, particularly if handled as American and British officers—so far as one can judge from their past exploits and their present character—could handle them. It was mainly the presence, towards the conclusion of the engagement, of torpedo-boats with Admiral Ting's shattered force that decided Admiral Ito not to attempt that which, no doubt, he might have otherwise accomplished; I mean the total destruction of the Chinese fleet. But the torpedo, to be a really potent factor, needs even something more than good men to handle it. If employed from boats, the boats must be fast, to begin with, and must have been carefully looked after, so as not to have materially deteriorated; if employed from ships, the torpedo-tubes must be either submerged or protected by armor. I venture to quote in this connection a passage from a carefully compiled account of the recent hostilities in the China seas, which

I have contributed to the as yet unpublished edition of Lord Brassey's "Naval Annual" for 1895: "All the Chinese ships went into action with torpedoes in the tubes and second torpedoes, without pistols, ready in the loading trolleys. But when presently shots began to enter the above-water torpedo-rooms the people took off the heads of the spare torpedoes and stowed them below; also, in some vessels, flinging the pistols overboard. In the Chen Yuen, a little later, several torpedoes were discharged to sink immediately, as their presence was supposed to constitute a danger to the ship. Immediately afterwards the stern tubes were actually struck by a Japanese shell. In the Ching Yuen, for the same reason, the torpedoes were hurriedly discharged, but not so as to sink, and two of them were picked up after the action. Whether the same thing happened in the Chih Yuen and King Yuen is not known, and, consequently, it cannot be determined whether or not the sudden catastrophe to the Chih Yuen was, as has been suggested, brought about by the explosion of a torpedo in one of her broadside tubes, but it is very probable that it was so." It should be added that all the experiments of which I have any knowledge—and these include a considerable number of which I have been a witness—lead me to suspect that a determined torpedo-boat attack, even by daylight, would not be so utterly hopeless an affair as is commonly imagined. If the boats, taking advantage of a lee afforded, say by ironclads or by neutral vessels (and one must admit the possibilities that neutral craft may be so used), could get within 2000 yards of their prey, not only, so I believe, would they succeed in a large proportion of their attempts, but also they would succeed with remarkably small loss. Even at 4000 yards, if helped by smoke, their prospects would be good. Modern boats, it must be remembered, and especially those of the "destroyer" class, are good sea-keepers and have a very respectable radius of action.

With the essayist's suggestion that, in certain circumstances, it would be desirable to substitute for the present long guns weapons of less length and greater caliber, I cordially agree; indeed, I have myself advocated something of the kind. For some vessels an armament of R. F. guns and B. L. howitzers seems to be peculiarly indicated.

I feel complimented when I see the large space which has been devoted by Lieutenant-Commander Wainwright in his paper to comments upon the various questions which I was permitted to formulate in No. 70 of the Proceedings. I am only afraid that he has given too much attention to points which will inevitably be answered by every commander in his own way when the moment for action arrives. My object was rather to suggest subjects for thought than to suggest topics whereon conclusions of a "regulation" character ought to be formed. I regard, however, as well worthy of attention the advice that war-ships shall carry collapsible boats either behind armor or below the protective deck.

Lieutenant-Commander WAINWRIGHT, U. S. N.—In endeavoring to reply to the criticisms in this discussion great difficulty is encountered in keeping the matter within reasonable space limits. The field is wide and there is ample room for reasonable differences of opinion, so that to properly state any one side of the question would frequently require the limits of an essay. The one raised by Commander Goodrich is of great importance, and many pages of the Proceedings could be filled in fully developing the subject. If in this discussion I fail to reply to any criticism it is not from want of appreciation of its importance, but because time and opportunity do not permit.

First as to the place and functions of an armored cruiser or battle-ship of great coal endurance. I believe it is but a substitute or make-shift for a heavily armored battle-ship of limited coal endurance. A homogeneous fleet of an inferior type of battle-ships would be better than a heterogeneous fleet with ships on the average of a somewhat superior type. The importance of this tactical fact cannot be exaggerated; but the absence of coaling stations requires that the United States should have some vessels of this type. It is possible that even with sufficient properly protected coaling stations that the time consumed in coaling may be of sufficient importance to require in some a sacrifice in defensive armor for the purpose of greater coal endurance.

I do not believe with Lieutenant-Commander Schroeder that it is a valid reproach to the echelon formation that it is not elastic, and that before entering another formation the squadron has to form line or column; for the reason that I believe line, column and echelon to be the only formations for battle and therefore no greater elasticity is required. As to the distances being sometimes thrown out in entering or leaving echelon formation, this only occurs when echelon is formed to the front from line or line formed to the front from column. This should not be done in the face of the enemy. In fact, the line of battle consists of line ahead, or column, line abreast, or line, and bow and quarter line or echelon, and the only changes of front permissible in face of the enemy are those made by vessels changing direction simultaneously or with vessels in column by change of direction in succession following head of column, the distance in all cases between vessels remaining unaltered.

Lieutenant Meigs is certainly correct in his statement of the necessity of increasing the rapidity of ammunition supply, and it seems as if some system similar to that used in libraries for the delivery of books might be adapted to this purpose. In any case, for the complete development of rapid fire, a supply of ammunition must be kept on hand at the guns. Ordinarily the occasions when it is advisable to use extreme rapidity of fire would be few and last only a short time; in other words, the ready magazine would be used only as an emergency similar to the use of the magazine of small arms.

The adoption of shorter 16-in. guns for the high-powered 13-in. guns may be advisable. At present it would be prevented by the greater length of time between fires owing to increased weight of projectile and of breech block. Improved methods of handling ammunition and loading, and the adoption of rolling breech blocks, may overcome these difficulties.

Professor Alger has erected his own man of straw and then successfully knocked him over. I hardly think that any seaman would contemplate pointing otherwise than at the center of the target when distant 2000 yards; but as I believe that the crucial portion of the combat will be fought usually at less than 1000 yards distance, the point at which to aim becomes important. Chance shots at the opening range may inflict some damage, but it is at close range, within the danger space of the guns, that one vessel will silence the fire of the other and then drive her off or destroy her. The essay might have been clearer upon this point.

Lieutenant Niblack does not believe in unbending chains. I think that it would be dangerous to depend upon cutting stoppers and running the chain clear to the bitter end, as would be necessary should the anchor be let go by a collision. The mere act of bending the chains when they are not run below to the lockers is not a serious task. A compromise might be adopted and the chain unshackled abaft the bitts, unless there were gun positions forward of them, when the swaying end would be a danger in case of letting go.

Lieutenant Niblack's suggestion as to the application of a field telephone service to ship's uses is admirable. I do not think range-finding in action by any of the present methods, except with the guns, is of much importance to the gunners, and I have great doubts as to the importance of the weather-gauge. With modern vessels, running at high speed, it will be a strong breeze that makes the smoke obscure the enemy. I think the question of handling the guns in a seaway and that of exposure below armor belt are more important. The lee-gauge at times might be objectionable from the increased exposure below the armor belt, and it might be an advantage as allowing the guns to be handled with greater facility.

Mr. Clowes evidently believes in under-water torpedo-tubes or he would not adhere to the point that the fear of the torpedo with the gun fire will render close action very infrequent, for he admits the inefficiency and sometimes danger of above-water tubes. I believe that submerged tubes are at present inefficient and that torpedoes are of little value on cruisers or on battle-ships, and that in spite of "the terrible effect of heavy-gun fire at short ranges" the battle will be finished frequently at very close range. Therefore ramming will be an important factor and one necessary to be considered carefully in the present state of naval weapons.

It is especially pleasing to me that Mr. Clowes believes that I have been able to distinguish the limitations of the teachings of the past, for in that particular my able critic in the New York Herald thought I was in error and seemed to believe it even more dangerous or useless to apply the facts gained from the history of past naval battles to the conduct of modern conflicts than to apply the history of stage coaches to the conduct of railroads. Although only slightly acquainted with the subject of stage coaches or of railroads, I venture to assert that if one were unable to obtain the benefit of the experience of the methods in use at present in railroad affairs he would be benefited greatly by searching through the history of stage coaches and ascertaining the rules that then governed the transportation of people and freight and then endeavoring to modify his rules so as to satisfy modern requirements. Without doubt, experience in battle with modern weapons can alone settle many problems, but it is certain also that the best substitute for experience with present weapons is the study of former battles. I do not believe that there is any danger of being induced by such study to misapprehend the great changes in weapons in the elapsed time.

Lieutenant Glennon's criticism of the movements of the A and B fleets is quite just as far as he goes; but he has only made another move for the B fleet, and A must make the proper reply. Should the right flank of A not overlap B's flank, and should A turn in pursuit to the same course as B, the latter would have the advantage; but should A gain ground to the right by running in column along the line of bearing until his right flank overlaps B's flank and then turn in pursuit, the advantage would be with A. B may then endeavor to gain ground with the port helm, forcing A to give a stronger sheer, and the final result be to bring the two fleets in parallel columns running in the same direction, as will be generally the case with two fleets handled equally well. It is not necessary to carry in the mind the lines of fire of the different vessels to get an average distance. The fleet having its center nearest the flank of an enemy has the advantage in position, and one of the points for which to strive is to have the distance between your center and one flank of the enemy shorter than the distance between his center and either flank of your fleet.

I must take advantage of this opportunity to thank my friends for their pleasant compliments, especially those who have so kindly criticized the essay.

WATER MOTORS AS MARINE DYNAMO DRIVERS.

By Lieutenant F. J. Haeseler, U. S. Navy.

It is desired to present for consideration the feasibility of the use of water motors on board ship for the purpose of driving the dynamos and also the ventilating fans. An outline of the proposed scheme is as follows: That there should be duplicate dynamos, of a *commercial high speed type*, designed for running at about the commercial speed when belt driven; these dynamos to be direct coupled to the shafts of water motors of the most approved and economical type in the market, and these motors to be actuated by water from the steam fire pumps, also in duplicate; the waste water to be pumped overboard by a pump in the dynamo room, or pumped into the flushing system with an overflow, or to be returned through a return pipe to the pump in the fire room. In the following comparison the last of these three methods will be chosen to illustrate the working of the system.

In connection with the above outline the points to be considered are: 1st. Original cost; 2d. Expense of maintenance; 3d. Advantages and disadvantages.

First—Original Cost.

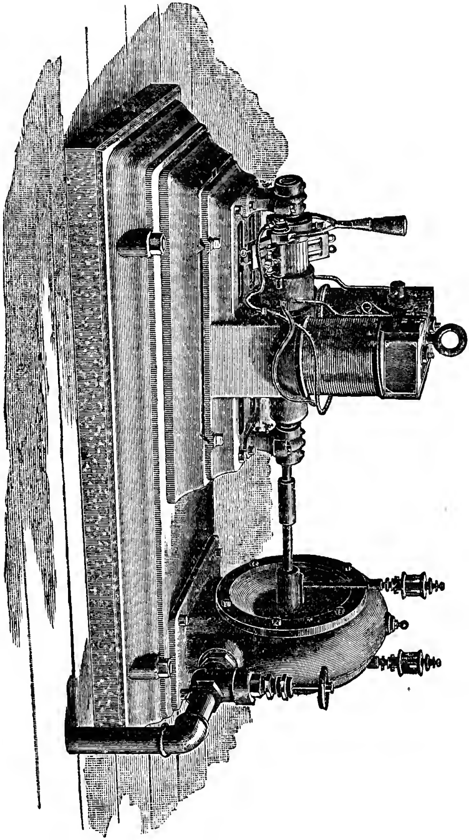
With reference to the expense of installation, the only considerations are those involving changes; the wiring, fixtures, etc., remaining the same, the cost of the generating set only is to be considered. The cost of the piping will be practically the same, for while it will take slightly larger pipes for the water than for the steam, yet there will be saved the cost of the separator and reducing valve, which together will easily cover the additional cost of the increased size of the pipes. The articles that will be dispensed with by using the water system will be the dynamo room electric motor and fan, the separator and the reducing valve. It will be necessary to increase the fire pumps in size over what they would naturally be for the ordinary service for which they are intended, and in the table at the end of this paper, under the head Steam Pump, is meant the *increase* in size of pump necessitated. By reference to the table just quoted it will be seen that the cost of the complete generating set of the steam system is $6500, while that of the water system is but $1380, showing a saving of $5120 on *each* of the generating sets of the ship. The prices given in the table were obtained as quotations direct from the manufacturers and are correct.

SECOND—COST OF MAINTENANCE.

This head is subdivided into Efficiency, Attendance, Repairs, and Lubricants.

Efficiency.—The specifications of the Bureau of Equipment require for the different sizes of the generating sets efficiencies varying from 76% with the 8 kilo-watt set to 82% with the 32 K. W. set, *at full load.* It will be seen by the table already referred to that the efficiency of the steam plant *at full load* is greater than that of the water system; but *at half load,* which is about what is carried nineteen out of the twenty-four hours, the efficiencies are about equal, or slightly in favor of the water plant. The above comparison is made allowing that the efficiency of the steam engine remains as high as when tested on shore before installation, which I have no hesitancy in saying—and experience has corroborated my statement—it does not. Further, the use of a slow speed pump admits of the installation of a compound steam end, which will result in a saving of at least 20% (pump makers claim 30%) in fuel, which, after all, is the only true basis of comparison. The water motor and dynamo will be as efficient at the end of a cruise as they were the day they were installed, and the fire pump being a slow running machine, with very little friction and very few parts, and being driven at less than half its maximum speed, should have very little wear, so that the efficiency of the entire plant should remain nearly as high during the entire cruise as it was when first tested. The details of the computation of the data in the table referred to and the data of the tests made of the Pelton Water Motor are given in an appendix to this paper.

Attendance.—At present we have at least three, and generally four, gunner's mates to attend the dynamos and engines on board ship. On a vessel carrying duplicate 24 K. W. sets, there would be two gunner's mates, first class, at a pay of $40 per month each, and two gunner's mates, second class, at a pay of $35 per month each, or a total cost of attendance of $150 per month. By the introduction of the water system, the expert attendance needed *only* by


WATER MOTOR WITH DYNAMO CONNECTION.

the high speed engine would be unnecessary, and one of these gunner's mates, first class, and both of the gunner's mates, second class, could be replaced by apprentices, first class, at a pay of $21 per month. This would leave the one gunner's mate, first class, in charge and to attend to the repairs to the wirings, search lights, fixtures, etc., and the three apprentices would stand watch in the dynamo room. This would effect a saving of $47 per month, which represents about 25% of the coal bill of the dynamos. Further, it would help in giving electrical instruction to all the seaman apprentices, first class, of the ship.

Repairs.—The experience of the users of the water motors of the Pelton class shows that absolutely no repairs are necessary, while the repairs on the pumps will probably be no greater than those arising from the wear and tear on the flushing and fire pumps which they replace. The pumps would, of course, be designed for the work to be done, and should have very little repairs; and it is well known that pumps if run much below their maximum capacity will keep up their efficiency for years of steady running, with an occasional renewing of the packing or the refitting of the valves. On the contrary, the marine dynamo engine is constantly being repaired and its parts renewed at considerable cost. In all the reports from the Bureau of Equipment on the subject of "Electricity on Shipboard," the breakages of the engines take precedence in the list of accidents to which the generating set is liable. In doing away with the high speed engine and substituting a machine that is practically indestructible in use and never needs repairs, we do much towards making the plant perfectly reliable.

Lubricants.—The present method of running the dynamo engines without oil in the steam spaces reduces the consumption of oil very considerably, but it is very questionable whether it does not do so at the expense of the engines themselves. I am fully aware that engines can be and are so run, and that the interior of the cylinder gets a beautiful polish on it, and shows no sign of wear after long use; but that is the case on shore where the engines are fixed to firm foundations, get the best of care by trained men, and are not tossing about, frequently at an angle of 30°. But even without the use of oil in the steam spaces the marine dynamo engine has a dozen oil cups where the water motor has two, and without having any data at hand that will positively show what the saving in oil would be, it is a very safe estimate to say that there would be required less than one-half the amount of lubricants in the dynamo room that there is at present.

Summing up under the head of cost of maintenance, we see that the efficiency of the proposed system would be *at least* equal to the present, that the saving in attendance, repairs and lubricants is marked, and that therefore the cost of maintenance of a plant on the water system would be less than on the steam system at present in use.

THIRD—ADVANTAGES AND DISADVANTAGES.

The evident *additional* advantages of the water system over the steam system are as follows:

1st. Ordinary temperatures in the dynamo room.

2d. Absence of dirt and oil in the dynamo room.

3d. Absence of thumping of engines in the dynamo room.

4th. Great reduction in weight (see table).

5th. Reduction in the space required for dynamo room.

6th. No need of carrying spare parts.

7th. No lagging of pipes nor expansion joints.

8th. Possibility of replacing dynamo or motor in any market.

9th. No danger to human life due to defective or ruptured pipes.

10th. Possibility of coupling either dynamo to either motor, or both dynamos to the same motor, or both motors to either dynamo, and, if desired to run both dynamos at exactly the same speed, both motors and both dynamos could be all coupled together.

These advantages require no explanation nor data to show that they would exist; they are self-evident, and the first-mentioned, that of absence of all unusual heat in the dynamo room, and therefore on the berth deck or other living spaces or store rooms in the neighborhood, is of enough importance in itself to merit an investigation into the claims made for this system.

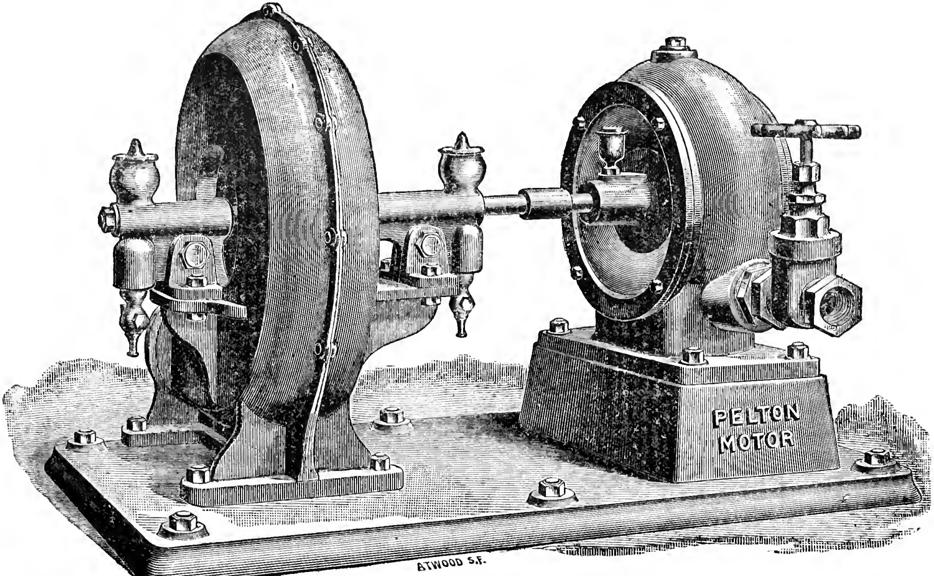
In connection with this subject there are two points not yet touched on: that of governing and that of reserve power. Of the former I *know* that the Tuerk or Syracuse Water Motor will govern as efficiently as the present steam engine governor; but the efficiency of this motor is so low that it would cost too much coal to run it, and, further, it has a more delicate and intricate construction, one that might get out of order, and would require a certain amount of attendance. The testimonials published by the Pelton Water Wheel Co. go to show that they also have a perfectly reliable governor. It is unfortunate that I have not as yet had an opportunity of testing the Pelton governor to see if it would meet the requirements of the Bureau of Equipment for governing. The small governor made by this firm will meet all demands on it from full load to no load, if the load is not varied by too large a quantity; but it would be a very simple matter to have a test of the Pelton differential governor made, so as to see just how well it would meet the demands. If their governor meets the claims of the Pelton Company as well as their wheel does, it will be all that would be necessary. At the same time I am inclined to believe that a much simpler governor could be designed, something on the general plan of the Willans steam governor, and I have sketches of two designs for this purpose: one controlling the valve motion by electricity, and one by the speed of the motor shaft. If it was found that the electrically controlled governor would work satisfactorily, it would admit of the discarding of the hand regulator in the shunt, and then the *only* duty of the attendant would be to fill the three or four oil cups on the generating set and see that the dynamo brushes were properly set. Either of the designs of governor just mentioned would require no power to run them except at the moment of use, with the exception that the shunt coil of the electrical governor would take probably 20 watts to keep it excited, which amount of power would be practically nothing.

Reserve Power.—A water motor has a wider range of power, at a high efficiency, than any other class of engine. It is simply a question of the amount of water that can be provided for it. With the same Pelton wheel I have obtained 16-horse power at an efficiency of 86%, and $\frac{3}{4}$-horse power at 82% efficiency. Where is there a steam engine that can equal that performance? This same motor is capable of developing at least 60-horse power at the same high efficiency. It therefore becomes a matter of how much water the pumps can provide. In the pumps selected in this comparison, either pump, without running at its maximum speed, is large enough to run both motors with power enough to drive both dynamos to their full capacity. If, therefore, either pump was to break down, the other would be equal to the emergency in the very rare case of the necessity of running both dynamos.

Another advantage not mentioned is the possibility of starting up the generating set in a few seconds. With the steam set, if anything happens to the dynamo or engine it becomes necessary to warm up the other engine before it can be started, which requires at least five minutes, during which time the entire ship would be in darkness, which might delay the supply of ammunition or the training of the guns at a most critical time, or cause great confusion in the engine room.

The Ventilating System.

It is generally conceded that the present system of ventilation is wrong. We have the tremendous air ducts running through the ship, occupying berthing or coal space and, in all probability, ruining the water-tight bulkhead system, and the engines driving the ventilating fans of this system use steam, thereby heating the living spaces and store rooms by their admission and exhaust pipes. The fans must be run on the entire system in case an improvement in the ventilation is desired at any one point, and as the air inlets in each store room *will* be left open, the unnecessary work done is great. It has therefore been advocated by many officers of the service that between every two water-tight transverse bulkheads a separate blower be established, and that these blowers should be run by electricity. This would be a great improvement, but it would be still better to run the blowers by water motors. By the use of the latter there would be a number of advantages: first, a saving in coal, as the small water motor is more efficient than the small electric motor; second, a saving in cost, as an electric motor having the same power as a water motor would cost six or eight times as much; third, a saving in weight, as the same relation would hold as in their cost; fourth, the water motor would need absolutely no attendance, merely filling the oil cups once every four hours would be all the attendance necessary. With the electric motor, theoretically, no attendance is needed, but it is very liable to be damaged unless entirely encased, in which event it is very likely to heat excessively; and while the brushes, if once properly set, should require no further attention, still if a little dirt should get on the commutator, and it was not removed, it would be a matter of a very short time before the entire surface would be ruined, requiring turning down in the lathe. In the



FAN BLOWER RUN BY WATER MOTOR.

event of a hot bearing of the armature it will either slow down and burn out, or the fuze will blow, which is not desirable, as it would be at least a 20 ampere fuze, and that in itself would be liable to set fire to some of the woodwork in the neighborhood. In case of a hot bearing with a water motor, an event much more rare than with an electric motor, the machine would slow down and no damage would be done. The only advantage the electric motor has over the water motor is the ease of conveying the power to it,—wires in the one case and pipes in the other.

I have given an outline of the system of water motors that could be used on board ship, and the more the matter is looked into and discussed, the more apparent the advantages become. The water motor could be applied directly to the anchor hoist, saving a large amount in cost and weight; and, as in this event it would be located above the water-line, the waste water would run overboard, so there would be the saving of one pipe in case the exhaust is connected to the condenser, which it usually is. Here again comes the saving of undue heat in the living spaces, as every one knows what a nuisance an anchor engine is, on account of the heat given off by it for hours after it has been used. I think, however, that the advantages of the use of a water motor are nowhere so apparent and real as in running the dynamos and ventilating fans, even if the present system of large fans is continued.

	24 K. W. Naval Dynamo.	Dynamo Engine.	Complete Set without Dynamo Room Blower.	Complete Set with Dynamo Room Blower.	Steam Pump.	High Speed Dynamo.	Pelton Water Motor.	Complete Set without Dynamo Room Pump.
Original Cost.........			$6500		$180	$900	$300	$1380
Weight...............	4608	2612	8800	9054	2200	2400	675	5275
Floor space...........			92″ x 45½″			50″ x 34″	14″ x 32″	64″ x 34″
Efficiency at full load.	90%	89%	80%	77%	90%	92%	86%	71.2%
" " halfload.	85.6%	78%	66.8%	66.6%	90%	88.5%	82.3%	65.5%

In the column of Steam Pump abreast Original Cost and Weight is meant the increase necessitated in the fire pumps by the introduction of this system.

APPENDIX.

COMPARISON OF EFFICIENCIES OF THE STEAM AND WATER SYSTEMS FOR DRIVING DYNAMOS.

The size of the generating set used as an illustration will be the 24 K. W. set of the present type, compared with a similar-sized dynamo driven by a 24-in. Pelton water wheel, using water at 150 pounds pressure and making about 700 revolutions.

THE DYNAMOS.

The commercial efficiency of the present naval multipolar dynamo of 24 K. W. capacity is about 90% at full load, the losses being proportioned about as follows:

	Watts.	Per cent.
Shunt loss C^2R - - - - - - - - -	778	3.3
Armature loss C^2R - - - - - - - -	833	3.7
Hysteresis, friction, etc., - - - - - -	700	3.0
	2311	10

If now the load be reduced to one-half, the losses in the shunt and those due to friction, etc., will remain the same, or, summed together, will be 6.3% of the full load, or 12.6% of half load. The armature loss will be $(\frac{1}{2})^2 \times 3.7\%$, or .9% of full load, or 1.8% of half load, so that the entire loss will be 14.4% and the dynamo efficiency will fall to 85.6%.

For the high speed commercial dynamo for the water set, I have selected a 24 K. W. compound wound Lundell dynamo, running at 700 revolutions and having the same voltage as the present naval type. The compact and ironclad form of this make of dynamo, together with its very high efficiency, makes it particularly suitable for the work required of it. The losses are as follows at full load:

	Watts.	Per cent.
Shunt loss - - - - - - - - - - -	684	2.5
Armature loss - - - - - - - - - -	800	2.95
Friction, etc., - - - - - - - - - -	690	2.55
	2174	8

This gives a final efficiency of 92% at full load. At half load we have losses as follows: Shunt loss 5%, armature loss 1.45%, friction, etc., 5.1%, combined loss 11.55%, or the efficiency at half load falls to 88.45%.

The data for the Lundell dynamo were obtained directly from the Interior Conduit and Insulation Co. of New York and were from actual tests. As the dynamo was belt driven when tested, its efficiency would probably have been higher had it been connected direct to the shaft of a water motor, thereby saving the binding friction on the bearing at the pulley end of the machine.

There are many instances quoted by reliable authorities giving 94% and in some cases 95% efficiency for high speed dynamos. The General Electric Co. quote a 4 pole 25 K. W. dynamo, running at 1050 revolutions, on which it will *guarantee* 90% efficiency, but state that it will run higher than that figure. The C. and C. Electric Co. quote on a bi-polar 25 K. W. dynamo 91% as a guaranteed commercial efficiency. Therefore the 92% quoted by the Interior Conduit Co. is probably correct, and can easily be attained.

THE PUMP.

The efficiency of the modern direct-acting pump runs very high. Correspondence with the Worthington, Blake and Dow pump-makers establishes at least 90% as their efficiencies when everything is in good working order. At first thought this seems too high, but a little consideration and investigation will show that this is not unreasonable. An old-fashioned pump having 80% efficiency was considered very good; but that class of pump had a fly-wheel, crank, connecting rod, etc., and not as much thought had been expended on the details of the design; the openings were frequently insufficiently large and the valves were leaky. Further, the presence of the fly-wheel, so advantageous generally where unequal stresses were brought on a machine, was detrimental for two reasons: first, because its own weight and the action of the thrust of the connecting rod on the crank pin absorbed a large percentage of the work, due to friction; and, secondly, because the weight of the fly-wheel actuating the plunger of the pump, which was moving an *incompressible* and *inelastic* body, caused its power to be delivered like a blow, and there was great loss by impact; so that now, with a slow-moving, direct-acting pump, the steam cushions its own blow, giving it the effect of a *push* instead, and with almost no friction, we naturally can expect and do get high efficiencies.

Professor Robert H. Thurston, of Cornell College, in an article on the Contemporaneous Economy of the Steam Engine, in the Transactions of the American Society of Mechanical Engineers for 1894, gives all the data of an actual test of a pumping engine having a commercial efficiency of 90.78%, and states: "The friction of the engine is remarkably low for this type of pumping engine, but it is, *of course*, still *above* the figure obtained from the best direct-acting machines, which, in the Newtown, Mass., trial reported recently, for example, was found to be 4.2%, giving a mechanical efficiency of .958 as compared with that here obtained of .9078." By friction of the engine Prof. Thurston means the difference in horse power between the I. H. P. of the steam engine and the hydraulic horse power of the pump, as the data accompanying his report show. He further states that the Newtown, Mass., percentage of efficiency is somewhat higher than usual. It sounds paradoxical, but a little reflection will show that the greater the number of expansion cylinders, the lower the efficiency of the engine; therefore for a duplex simple pump the efficiency will be higher than for a triple or quadruple expansion engine. The reason of this is that there being more parts to the compound engine there is more friction, and therefore lower mechanical efficiency, but when we compare the coal consumed, then the advantage of the compound engine asserts itself. Quoting from a letter from the Blake pump manufacturing firm, we have: "Under favorable conditions, when running at its maximum, the efficiency will be in the neighborhood of 90%, and when only doing one-half the work this will probably be increased to 95% or 94%. The enclosed tracing shows cards taken by the writer from a Blake triple compound pump, with steam jacketed high pressure cylinder. In this case the efficiency was 93.2%, which is quite remarkable when all the places where friction is produced are considered."

Mr. Dow, of the Dow Pump Works, writes: "We find the loss in I. H. P. of our non-compound direct-acting steam hydraulic pumps, as we have furnished the U. S. Gov. boats Oregon, Olympia and Monterey, to in no case exceed 10% at full capacity, and 5% at half speed. . . . The high efficiency you refer to, 95-96%, in large pumping engines is correct."

It is therefore safe to assume that the pump can have an efficiency at least as high as claimed for it, 90%, at *full load for the dynamo*; this will be but *half load* for the pump. The reasons the efficiency rises as the load is decreased in a pump are as follows: The friction depends directly on the pressure and speed, and as the speed varies directly as the amount of water required, at half load there will be but half speed, and as the pressure remains the same there will be just half the mechanical friction or the same loss per cent; but the water friction varies as the square of the velocity of flow, and as this at half load is half what it is at full load, the loss by friction will be but one-quarter. Therefore the efficiency should be and is higher. Still, to be on the safe side, I have taken the efficiency at *half load*, which will be only *one-fourth* the capacity of the pump, as 90%.

The Engine.

The efficiency of the high speed engine is about 89%, the loss being due entirely to clearance and friction. This loss, as the *speed remains constant*, is always the same; therefore at half load the engine efficiency will be 78%.

The Water Motor.

The water motor used in the before-described comparison is manufactured by the Pelton Water Wheel Co. of San Francisco and New York. I have tested other makes of water motors, and read of still other tests, and it has been my experience, as well as that of others making comparative tests with these motors, to find that they are at least 15% and in some cases 35% more efficient. The firm claims an efficiency of 85% when the wheels are set in accordance with their instructions, and I have found their claims not only true, but below what is really obtainable. During the past two months Ensign W. H. G. Bullard, U. S. Navy, and the writer tested one of the Pelton wheels bought out of stock two years ago, and without any expectation at that time of its being tested for efficiency. Tabulated below are the results of our tests, showing an efficiency at the higher pressures in excess of that claimed by the firm. Tests Nos. 1, 2, 3, 10 and 11 were made with the motor running at incorrect number of revolutions, in order to determine the efficiencies when governing, in case the pressure on the whole jet was reduced and the revolutions kept up. Test No. 13 was the last one made, and it was noticed that the brake was binding closely on one side, which may have occasioned the lower efficiency.

TESTS OF PELTON WATER MOTOR No. 4.

Made by LIEUT. F. J. HAESELER, U. S. N., and ENSIGN W. H. G. BULLARD, U. S. N., at the United States Naval Academy, March, 1895.

Test No.	Size Jet.	Running Pressure.	Revolutions.	Water used. cu. ft.	Actual H. P. Developed.	Theoretical H. P. Possible.	Per cent Efficiency.
1	$\frac{5}{8}''$	90	775	14.05	4.101	5.496	74.6*
2	$\frac{5}{8}''$	105	910	15.14	5.025	6.910	72.7*
3	$\frac{5}{8}''$	100	850	14.78	4.694	6.422	73.1*
4	$\frac{5}{8}''$	100	775	14.78	5.349	6.422	83.3
5	$\frac{5}{8}''$	103	780	15.00	5.563	6.715	82.9
6	$\frac{3}{4}''$	125	880	23.05	10.73	12.52	85.69
7	$\frac{3}{4}''$	102	775	20.82	7.845	9.226	85.02
8	$\frac{3}{4}''$	100	775	20.61	7.756	8.957	86.59
9	$\frac{3}{4}''$	125	900	23.05	10.67	12.52	85.16
10	$\frac{3}{4}''$	73	775	17.61	4.457	5.587	79.79*
11	$\frac{3}{4}''$	86	880	19.11	5.365	7.143	75.12*
12	$\frac{3}{4}''$	100	780	20.61	7.717	8.957	86.15
13	$\frac{3}{4}''$	142	900	24.56	12.84	15.16	84.70

* Tests marked thus were made to find the efficiency of the governor.

A Prony brake was used, with a stream of cold water running over it all the time, and two pieces of soap bearing against the pulley, like the brushes of a dynamo, kept the brake equally lubricated, and the pull on the scale was very steady. The pull was measured by a spring balance, the brake arm being kept horizontal all the time, and the balance was compared with the standard after each test, and in several cases the standard itself was used. The standard balance was verified before and after the series of tests and was found to be accurate. The amount of water used was *absolutely measured* by running it into the pool of the natatorium of the Naval Academy, where the level of its surface could be measured by means of a float and rod that could be read with exactness to the one sixty-fourth of an inch, which corresponded to just one cubic foot. Thus the need of any formulae or miners' inch measurement was obviated. In this manner a number of tests were made, and the coefficient of ajutage found to be 95% with the ⅝-inch jet, and 92% with the ¾-inch jet, which agrees very closely with what they should be when worked out theoretically. After the coefficients were determined and found to be practically constant, the ⅝-inch jet not varying 1% in a range of pressures from 20 to 100 pounds, and the ¾-inch jet not varying at all in from 15 to 50 pounds, the water motor was moved to the power house, close to the pump, so as to get rid of pipe friction and have the pressures more under control, and at the same time higher pressures were obtainable. The amount of water then used was determined by using the coefficients of ajutage found as already described. The efficiencies thus determined can therefore be taken as being reliable, and agree with those in testimonials published by the Pelton firm. In this connection it is a matter of interest to quote from a letter from the Pelton Water Wheel Co. on the subject of efficiency: "Regarding the efficiency of our wheel when carefully made, especially for test purposes, would say that several years ago we sent a special test motor to Professor Reuleaux of Berlin, who obtained an efficiency between 90% and 91% from same. . . .Referring again to the installation at Fitchburg, the efficiency shown by the wheels there is fully 86%, the power delivered by generator is easily ascertained from the station instruments, and taking the *theoretical* discharge of the nozzles—no allowance whatever being made for nozzle friction—the efficiency of the wheels was 86%."

The efficiency therefore of the water motor *at full load* is 86%. This loss of 14% is made up of several things: friction of machine, friction of water in buckets, loss by impact on edge of bucket, etc. Of these the friction of the machine alone remains constant, as the speed remains the same; as the water is throttled down the pressure is reduced, and to keep up the efficiency the revolutions should be reduced correspondingly; but this cannot be, as the speed of the dynamo must remain constant; hence the efficiency will fall to about 75%. (See tests Nos. 6 and 11.) Here we throttle 125 pounds and 880 revolutions down to 86 pounds and 880 revolutions, and the efficiency falls from 86% to 75%. This can be obviated in two ways: first, by using a number of jets, say four, two of them being fitted with throttle governors, and by automatically or by hand cutting out a jet when the throttling reduces the power by an amount equal to the power developed by one jet. By this means we retain our 86% efficiency on two of the jets as long as the load is above one-half, so that we would have, at the lowest possible efficiency, two jets of 86% and one of 75%, or a combined efficiency of 82⅓%. Another and apparently simpler method of keeping up the efficiency, and one that I think is mechanically practicable, is to have one or more jets that can be varied in size of opening according to the power required. In this case the efficiency would not fall below 84%. But we will allow that we cannot get over 82⅓% at half load; hence we have 86% at full load and 82⅓% at half load as the efficiencies of the water motor.

Combining these efficiencies we have for the steam system at full load 90 × 89 = 80%; for the water system at full load, 90 × 92 × 86 = 71.2%. At half load we have for the steam system 86 × 78 = 67%, and for the water system 90 × 88.45 × 82⅓ = 65½%.

But in every dynamo room where the dynamos are run by steam there is an electric motor and blower to help keep the room cool; the size of this blower varies from ½-horse power to 2-horse power, and as these small motors have not efficiencies over 75%, it will be safe to say that the average blower installed with a 24 K. W. set uses 1¼-horse power from the output of the main dynamo.

We therefore have finally for the efficiency of the steam plant, meaning thereby the ratio between the power produced at the dynamo terminals, less that required for running the blower, and the I. H. P. of the engine, at full load 89% × 86½% = 77%, and at half load 78% × 79% = 61.6%. In these combined efficiencies it will be seen that the power needed to run the dynamo room ventilating blower is taken into account in computing the efficiency of the dynamo where it is considered as a loss.

THE GROWTH OF U. S. NAVAL CADETS.

By HENRY G. BEYER, M. D., Ph. D.,
Surgeon U. S. Navy.

The study of the growth and the development of the human subject has always been one of great interest, not only to the physiologist and statistician, but also to the general reader. While, however, growth seems to be the most natural thing that occurs in the animate world and in living things, some of the mysterious laws that govern the process are still involved in obscurity.

One of the means for the study of *human* development is anthropometry. By it we are enabled to record the progress that has been made in the different dimensions from time to time, and, providing our material is sufficiently large, to form our conclusions accordingly.

Thus it has been the custom at the Naval Academy for the last thirty years or more to make an annual physical examination of every cadet in training at that school, and, at the same time, to keep a record of certain anthropometric measurements of every cadet undergoing such examination. As the material that has accumulated in this manner is now sufficiently large, it would seem as if it were a duty to attempt a systematic study of these valuable records, with the view of contributing something to our present knowledge of the subject of growth.

As regards the nature of the examination itself, it is well known to all interested in the subject of anthropometry from the items that are recorded, and needs, therefore, not be described in detail. Up to a few years ago the height standing, perineal height, circumference of chest, waist measure and the lung capacity were the only items recorded. Within recent years the height sitting, span of arms, strength of squeeze, acuteness of vision and hearing have been added to these records. The number of observations under the first-named items is, consequently, much larger than that under the last named.

The fact that all the measurements are taken and recorded by medical men is sufficient guarantee of their accuracy and adds no little value to the results we may derive from them.

The cadet who stays the full term of four years at this school leaves on the books the records of five successive examinations taken one year apart; after graduation two years are spent at sea, after which time the cadet returns to the Academy for his final examination, leaving the records of another physical examination. This makes six in all. Since the age for entrance into the Academy is limited to from 15 to 18 years, and taking six years as the time necessary to elapse between the first and last examinations, the period of growth covered by these records ranges all the way from 15 to 24 years of age.

The circumstance that the cadets for the Naval Academy are appointed from all parts of the United States by their representatives in Congress ought, in our opinion, to add considerable weight in our attaching to whatever means or averages we may derive from their measurements a certain value, more national in character than can be attributed to the means and averages derived from the measurements of merely local schools and colleges. Besides, another point that is calculated to make our records particularly valuable is the fact that a large percentage of them are continuous records. The number of cadets that enter annually may be said to have varied in the past between 60 and 80, and that of those who graduate between 30 and 40.

It is perhaps also of some importance to mention the fact at the beginning that, from the great preponderance of blue eyes and light brown hair prevailing among Naval Cadets, it is safe to state that the great majority of them are of Anglo-Saxon and Teutonic origin. It is not impossible that the school may have exercised and is still exercising a certain degree of selection from that type of men for its devotees.

STATISTICAL METHODS.

One of the greatest impediments to our progress in the study of growth in this country has undoubtedly been due to the fact that different observers have used different methods of recording the results of their investigations, and, consequently, these results are difficult of comparison.

As regards the methods of investigation used in the present inquiry and those of recording its results, I have adhered to those used by Prof. W. T. Porter in his work on the "Growth of St. Louis Children" as closely as possible and with the view of making my statistics strictly comparable to his.

A brief outline of these methods and our conception of them seems, therefore, essential.

Based on Quetelet's statements made many years ago, it has since been most generally assumed that all anthropometric measurements would be found distributed according to the laws of chance; that a large number of measurements, for instance, of the height of man would arrange themselves on either side of a true height. It has, furthermore, been assumed that this arrangement would be symmetrical on either side of the true height if the number of observations were infinite and if only accidental influences had been at work in each individual measurement in a given series.

Quetelet's theory has since been further developed by Stieda and Ihring and also by Galton. In the same manner Bowditch and Porter have adhered to the theory of Quetelet, and all their investigations are based on this theory.

Quite recently Boas has made the following remarks regarding the theory of Quetelet, viz: "Glancing over the curves representing large series of measurements, it strikes me that they conform to the laws of chance only in a general way and that considerable deviations occur quite frequently. . . . Assuming that there is a uniform ancestral type in a certain district, and that the conditions of life remain stable, we may expect that the people representing its offspring will be grouped around the type according to the laws of chance. Assuming, however, that there were two distinct ancestral types in adjoining districts, and that these types intermingled, we cannot foretell what the distribution of forms among the offspring will be. It may be that they will represent an intermediate type between the parental forms, in which case we might expect to find them distributed according to the laws of chance. But it might also be that they showed a tendency to reproduce one or the other of the ancestral types either pure or slightly modified, in which case the resulting curve would not conform to the laws of chance, but would show an entirely different character."

This view seems to be well taken and deserves our consideration all the more for the reason that the intermingling of different varieties of the same species is a well-known cause for variation. In view of cautionary signals such as the above, some comfort may perhaps be derived concerning our present material of observation from the fact above mentioned, that the preponderating racial type of man under investigation is undoubtedly Teutonic in character. At any rate, a sorting out of types different from the prevailing one being entirely out of the question, especially in the absence of all craniometric data, we have been obliged to follow the example of previous investigators, and will make a brief statement of the various methods employed in the present inquiry, hoping that whatever correction may have to be applied may apply to all alike in the future.

In Table I* are exhibited the observed distributions of the heights of 842 Naval Cadets aged eighteen years.

AVERAGE.—The average (A) was calculated according to Stieda, quoted by Porter, and which means the quotient obtained by dividing the sum (Σa) of the values (a) obtained in the individual measurements by the whole number of observations (n) : $A = \frac{\Sigma a}{n}$. The adjoining Table II will illustrate the method.

MEAN OR MEDIAN VALUE (M) can sometimes be found by the simple inspection of a series, if the number of observations is sufficiently large, but is more exactly determined by the following method, viz : The mean strength of squeeze of the right hand in Table II is obtained by adding the number of observations from above downwards until the sum cannot be increased by the next number in the column without exceeding half the total number of observations. Thus 111 is reached opposite 75 pounds; the next number below in the column (40) would make the sum 151, which is more than half (112.5) of the total number of observations (225). The mean is, therefore, greater than 75 but less than 80 pounds. Its exact position is found by interpolation. Half of the total number of observations is 112.5, which is 1.5 more than the observations up to 75 pounds; 1.5 is 3.7 per cent of 40, the observations at 80 pounds. Hence the mean is 75.46.

* The tables referred to will be found in the Appendix.

Some statisticians take the average to be the nearest approach to the typical value, and this seems to be the case whenever the distribution of measurements follows the laws of chance; others look upon the mean to be the better value as representing the type, while still others hold that neither of these values in their present application represents the true type. Bowditch says: "If A represent the average value of all the observations, then the value of $M—A$ will be a measure of the direction and extent of the asymmetry of the curve ST (curve of percentile grades), for this value will be zero when the curve is symmetrical, positive when the values of the lower percentile grades fall short of M more than those at the higher grades exceed it, and negative when the reverse is the case." An examination of his table and of the curves constructed from it shows that the asymmetry of the curves of percentile grades varies very much at different ages both in direction and amount. Bowditch states distinctly that "we must conclude, therefore, that the rate of annual increase, both in height and weight, is different at different percentile grades, or, in other words, that large children grow differently from small ones, and, moreover, that between the ages of eleven and fifteen years there is a striking difference in the mode of growth between the two sexes." We will refer to this point of the difference in the growth between tall and small children in some detail later on.

THE PROBABLE DEVIATION.—But neither average nor mean gives us any information as regards the manner in which the individual measurements of a series are distributed, and it is clear that two series with an identical mean or average may yet differ largely in respect of the dispersion of the individuals from the middle value, as the following numbers, taken from Porter, will show:

4, 5, 6, 14, 15, 16.
9, 9, 10, 10, 11, 11.

These have the same average (10).

A very convenient measure of the degree of dispersion or deviation of the individual members of a series from their common mean or average is that afforded by the "probable deviation."

Probable deviation (d) is that deviation from the middle value which, in a large series of observations, is as often exceeded as attained (Lexis, Porter). According to Boas, the *mean deviation* is more accurate than the probable deviation, which is no doubt true. Inasmuch, however, as the relation between the two must be constant, and as it was one of our objects to make the results of our investigations comparable with those of previous investigators, the preference was given to the probable deviation which was calculated in accordance with the following approximation formula:

$$d = \pm 0.8453 \frac{\Sigma\delta}{n}.$$

In accordance with this formula all the individual deviations from the middle value (average or mean) of a series must be added together without regard to whether they be plus or minus, and the sum divided by the total number of observations as shown in Table III.

The observed distribution shown in Table III must now be compared with the distribution of the observations of an hypothetical series constructed according to the calculus of probabilities. The observed and the theoretical series should correspond, providing the causes of the deviations are purely accidental. Since it is absolutely required that such a comparison must be made before it can be known whether the observations in any series can be treated by the methods of the theory of probabilities, Table IV is appended.

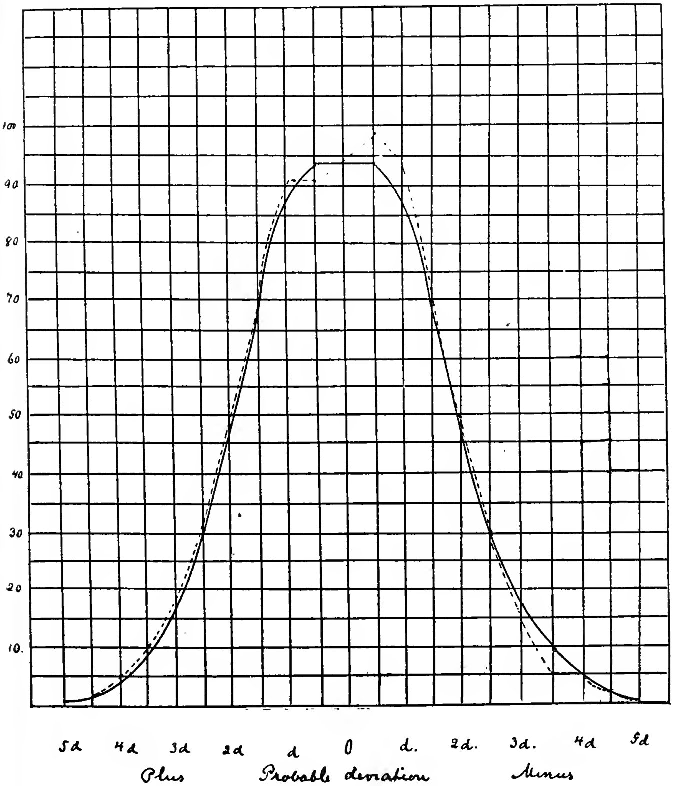
This table apparently shows that slight deviations do occur, and Bertillon proved this some time ago. Bowditch, also, has shown that the curves, showing the distribution of statures and weights of children, do not follow the laws of chance, by having pointed out the fact that during the period of growth a constant difference exists between the average and the probable values, an observation which we have also been able to confirm, as will be seen later on.

In the preparation of Table IV, Stieda's table, reproduced by Porter, and shown as Table V, has been made use of.

In order to bring out the relation between the theoretical and the observed observations still more clearly, Fig. 1 is appended, which is a graphic representation of Table IV. It is perhaps rather remarkable that the deviations of the observed from the theoretical curve are greatest about the mean, just where the numbers are largest and where, therefore, the agreement should be expected to be the closest.

FIG. 1.

The Calculated and Observed Distribution of the Height of 722 Naval Cadets aged 17. Unbroken line: according to theory. Broken line: according to observation.



PERCENTILE GRADES.—Another method for calculating the distribution of the observations in a series is the percentile method of Galton. According to this method the distribution of the observations is determined at intervals of 5 or 10 per cent from the median value.

Table VI shows the percentile distribution of 841 Naval Cadets aged 18 years according to this method.

Perhaps the simplest and, at the same time, the truest means for showing the distribution of, for instance, the height (or any other dimension) in a given series would be to arrange the members according to increasing height at intervals of, say, one-half inch, expressing in numbers the members found between every half inch.

THE PROBABLE ERROR (E) of the average was determined by the formula $E = \pm \frac{d}{\sqrt{n}}$ (Stieda, Porter),

where $E =$ the probable error of average,
$d =$ probable deviation of an individual from the average,
$n =$ number of observations in the series.

Table VII represents the values E as calculated according to this formula.

As was mentioned before, for the sake of uniformity and easy comparison, we have, in the preparation and tabulation of our material, adhered as closely as it was possible to the methods used by Porter. The period of growth covered by our tables is from 15 to 24 years of age, or, practically, to the termination of the growing period, although rare instances have occurred in which growth has been noted to have taken place even later. But such instances as these are extremely rare and can scarcely be called the rule. The tables of both Bowditch and Porter practically stop at the age of 16 years, for males at least, because their numbers after that age are very small and therefore not so reliable as those of the preceding ages. It seemed, therefore, that the material at our disposal might in a way be well calculated to complement theirs, and for this reason, if for no other, it would be very desirable to tabulate it so as to make them both in all respects comparable. We have, accordingly, calculated for every year here represented the average and the mean, the median minus average values, the probable deviations and the probable errors, as well as the 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 95 percentile grades. The 25th and 75th percentile grades, given in some of the tables, were obtained by dividing by two the sums of the 30th and 20th and of the 80th and 70th percentile grades respectively.

AVERAGES; MEANS; MEDIAN MINUS AVERAGE VALUES; PROBABLE DEVIATIONS.

These values are shown in Tables VIII, IX, X, and XI, and a brief discussion of them seems now in order.

According to Porter, "the mean or average of the observations at any age in the period of growth is typical of the child at that age, and a comparison of the means at different ages will reveal the law of growth of the type. Again, the mean of the observations at any deviation from the mean of the whole number, for example of the height at a deviation of $+d$ from the mean, or, if Galton's method be employed, the height at any percentile grade, is the type of those who stand at a certain degree of deviation from the type of the whole number. Thus the types of tall and short, light and heavy children are secured. The types of the same degree of deviation from the mean at all ages are as comparable as the type of the whole number of observations, and reveal the growth of the typically tall and short, light and heavy children; but the comparison is less secure the greater the deviation from the mean, for the probable error is inversely as the square of the number of observations, and the number of observations rapidly diminishes on either side of the mean."

This beautiful conception regarding the theory of the growth of tall and short children, however, has been quite recently most severely criticized by Boas in "Science." Boas expresses himself as follows: "We know of a number of facts which show plainly that the assumption is incorrect. It has been shown in Dr. Bowditch's tables that Irish children are shorter than American children. If the position of the American child is expressed in percentile grades of the whole Boston series and that of the Irish child in the same manner, it will be seen at once that they diverge more and more with increasing age. Pagliani's measurements of Italian children and my own of Indian tribes of different statures bring out the same point still more strongly."

Under these circumstances it would seem, perhaps, the safer plan to look upon the averages and the means not as the types themselves, but merely as the indices to the true types.

A mere glance at the tables of the averages and means shows at once that development and growth from year to year is anything but uniform and regular.

The praepubertal acceleration of growth in height, at first fully established by Bowditch and later on confirmed by Kotelmann, Roberts, Erismann and Porter, is also well shown in our tables.

According to Erismann, the period of accelerated growth, beginning with the advent of puberty and ending with the full establishment of sexual maturity, is completed at age 18.

We would add that a period of *retarded* growth follows immediately upon that of accelerated growth, after which period the curve again gradually makes a more rapid ascent towards the completion of the intended height. From age 20 growth is exceedingly slow. This fact is well illustrated in Table XII, in which, for the sake of comparison, I have added my own figures and those given by Porter to a table taken from Erismann.

In all the tables given here the ages have been calculated from the nearest birthday and not from the last birthday. The years, therefore, do not in all cases indicate the absolute age to which these figures belong, on account of the unequal distribution of the numbers within each year, that is to say, as the numbers between 15 and 16 years of age increase there must be a larger number of individuals between 15 and 15½ years than between 14½ and 15 years, so that the average age must be slightly higher than 15. The reverse must be the case, of course, when the numbers begin to decrease.

In connection with our averages and means, the measurements of Gould, taken during the war of secession, of a great many thousands of soldiers of different nationalities, are of some interest. The ages of the soldiers ranged between 31 and 34 years, a time of life when growth in height may most certainly be assumed to have been completed. They are classified as follows:

True Americans,	173.6 cm.
Southern States,	175.0 "
British America,	173.0 "
Englishmen,	170.1 "
Scottish,	171.3 "
Irishmen,	171.1 "
Germans,	169.6 "
French,	169.1 "
Scandinavians,	171.8 "
Spaniards,	168.4 "
Belgians,	168.6 "

Erismann believes that these different nationalities would not have reached this average height in their own native country, and that the different conditions of environment peculiar to this country caused this discrepancy. Topinard puts the average height of Frenchmen at 165.9 cm., and Beddoe places the average height of Englishmen in their own home at 169 cm., while the mean height of Italians, according to Topinard, ranges between 161 and 166 cm.

Roberts, speaking of the most favored classes of English people, in which class he includes naval and military men and university students, puts their average at 175.26 cm.

It was mentioned in the beginning of this paper that Naval Cadets, being appointed from every part of this country, ought to give us as nearly as possible an average that might be considered *national* in character. Now, the average height, as found in our tables of Naval Cadets, is 174.29 cm. at the age of 23, and the mean height is 174.04. If we take the average of what Gould calls true Americans and Americans from the Southern States we obtain 174.30, which is within 1-100 of a centimeter the average height of our Naval Cadets. This agreement of these averages ought to go far in establishing the average height of Americans as at 174.3 cm. when fully developed and of the class which these records cover.

Examining our table of averages a little more closely we find:

1. *Weight.* In weight there is an almost steady increase from the 15th to the 23d year, amounting in all to 37 pounds, the annual increase declining, of course, as age advances.

2. *Height.*—The greatest addition to height standing takes place between 15 and 16 years of age, after which age the annual increase rapidly declines and growth is distinctly retarded about the 18th year, whence again a more marked increase occurs, which comes to a close at the age of 21; a third upward curve leads to the attainment of the final growth.

3. *Height sitting* practically comes to a close at 19 years of age.

4. *Height perineal,* which is the height from the heel up to the perinaeum, closes at about the same age as the preceding.

5. *Circumference of chest* becomes highest at 19, to which it attains at rapidly advancing rates, and thence becomes steady or advancing only by small fractions of an inch.

6. *Lung capacity,* as ascertained by the spirometer, reaches its maximum at 19 and continues steady or varies only slightly.

7. *Waist* shows a continued increase up to the 23d year, remaining, however, stationary from 19 to 21, and after that continues to increase more rapidly.

8. *Span of arms.*—Its greatest increase takes place between 15 and 16 years of age; it then increases slowly but steadily until the 23d year.

9. *Vision.*—We notice here the significant fact that both right and left vision show a positive increase up to the 19th and 20th year. This fact seems of some importance in apparently demonstrating that the course of study at the naval school, and the strain that is necessarily put upon the organ of sight, does not in itself tend towards diminishing the degree of distance vision in an otherwise normally constituted eye, but that, on the contrary, it is rather advantageous in slightly but perceptibly increasing the visual range. The slight decrease in distant vision noticed at the 23d year would indicate to my mind and to those acquainted with life at sea and its requirements on those actively engaged in it, the result of undue strain.

10. *Hearing.*—As to hearing, it is perhaps equally significant that that organ is affected quite perceptibly, but in the contrary direction; we may notice here a gradual but steady decrease for both sides during the entire period under observation, and, no doubt, the occupation of Naval Cadets would lead us to expect just such a result.

11. *Squeeze* shows a steady increase, with but slight and unessential variations.

There exists some difference of opinion as regards the relation of the period of accelerated growth to puberty. If growth and procreation are, as they have been designated, antagonistic processes, we must agree with Bowditch, in that the period of accelerated growth is praepubertal in time. It would perhaps also follow quite naturally that the fullest establishment of maturity should be followed by a period of *retarded growth*, as is apparently shown in our figures of the annual growth. We do not find any great cause for controversy with regard to this question, nor do we consider it difficult to reconcile the opinions held by Bowditch on the one hand and by Pagliani and Carlier on the other. The beginning of the stage of puberty is not necessarily that of sexual maturity. Nature prepares the individual for sexual maturity and the process of procreation by inaugurating changes that are advantageous to the species and by causing increased development in various dimensions. This sudden wave of normal development completed, it results in sexual maturity becoming fully established and functional, and with its full establishment, growth in the different dimensions takes a short and much-needed rest, during which the organism at large sympathetically accommodates itself to the new order of things.

It is more than merely probable that the exact time of life when this praepubertal development begins is, within a certain limited range, different for every individual even of the same type and social class. In some it may come on a little sooner, in others a little later, so that these two phenomena must neutralize each other to a certain extent by this overlapping, and the probable result must be that the absolute praepubertal increase is actually larger than it is usually recorded.

Neither the average nor the mean gives us any information as regards the manner in which the individual measurements of a series are distributed, and it is clear that two series with an identical mean or average may yet differ largely in respect of the dispersion of the individuals from the middle value, as was shown above.

According to Boas, the mean deviation is the more accurate of the two, and which is no doubt true; but inasmuch as its relation to the probable deviation would be in all respects constant, and as it was one of our objects to make the results of our investigations comparable to those of previous investigators, the preference was given to the probable deviation.

Table VIII represents the probable deviations for the items that were available for calculation. It will be seen by this table that they are small, even when compared with those given in Porter's tables, which indicates that one-half of all the observations deviate but little from the middle values, and which fact is considered to be one of the fundamental attributes of all deviations due to accidental causes.

It is extremely doubtful from present appearances whether any further significance will ever be attached to the percentile grade system in the future than that of using it merely as a means for classifying anthropometric facts in percentages.

Boas, in his latest contribution to "Science," March, 1895, states that if the assumption is made that the same children remain on the average in the same percentile grades, a certain very complex law must follow; for any different law of growth, children would change from one grade to another. And Porter remarks that in order to determine the relation of the growth of the individual to the growth of the type we must have material that admits of the application of the individualizing method, and that the present state of our knowledge of the subject does not permit us the prediction of future growth.

I believe that the prediction of future growth, even after having accumulated a sufficient amount of material which will permit of the application of the individualizing method, will always form a difficult if not doubtful task, for the reason that we are unable to predict, at the same time, the causes that will influence individual growth.

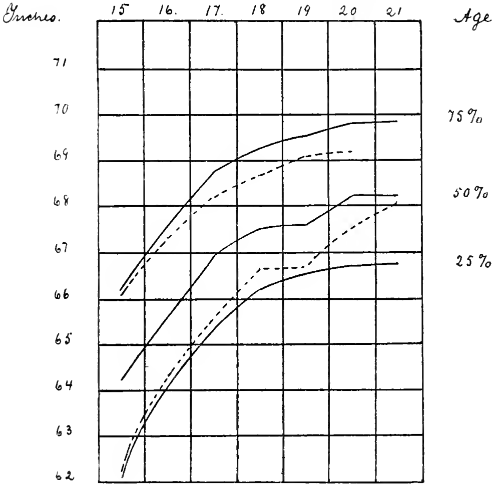
In the records at my disposal I find that their continuity is often broken by the omission of one or more items for one or more years in succession. This may be due to an oversight on the part of the examiner, or to a temporary inability on the part of the examinee to submit to that part of the examination. Hence if a very large number of such continuous individual records were required, even the material at my disposal would not be such as to definitely settle this question practically; and if I were to rely on broken records and put a larger number of these together and average them, I would simply arrive at about the same curves that are presented as the results of the whole number of observations. In fact, our averages and means and the deviations therefrom are the results of just such records, about 30 per cent of them being continuous and, with the exceptions mentioned, unbroken for the period of growth covered by them.

However, on searching these records I was able to find between 35 and 40 continuous records of individual cadets, each beginning with the 25th percentile grade in height as well as in weight, either at 15 or 16 years of age, and as many such as began with the 75th percentile grade in the same items and at the same ages. These, when examined individually and compared to the average progression of their respective percentile grades obtained from the whole number of observations that are recorded here, revealed the fact that not a single one of them remained in the grade to which it belonged.

The exact number of individual records belonging to the 25 percentile grade as to weight is 40, and that of those belonging to the 75th percentile grade is 36. As to height standing, there were 39 belonging to the 75th and 37 belonging to the 25th percentile grade.

FIG. 2.

Height.—Percentile and Individual Curves Compared.



Continuous lines: normal, 75, 50 and 25 per cent.
Broken lines: individual, 75 and 25 per cent.

The averages of these records have been tabulated together with the 25th, 50th and 75th percentile grades obtained from the whole number of observations, viz. Table XIII.

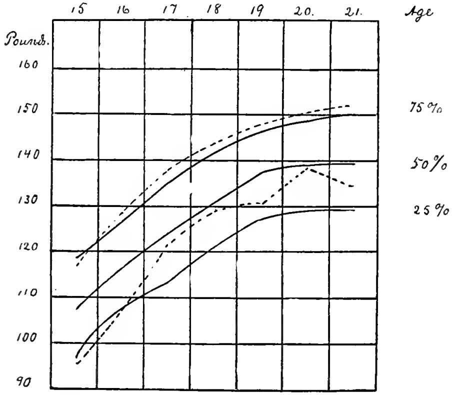
The relation which these individual averages bear to the general averages is best seen in Figs. 2 and 3 plotted from the tables.

The 25th percentile individual curve of both height and weight shows a marked tendency to approach the 50th percentile grade curve or the mean of all the observations. As to height alone, the 75th percentile individual curve likewise, but not so directly as the 25th percentile curve, inclines toward the curve of the middle value. In both the height-curves there is, it would seem, *a strong aim at the middle value towards the end of the period of growth.*

The curves, shown in Fig. 2, and a detailed comparison of the individual records with the normal percentile grades of their class, *would go far in convincing me of the fact that individuals do not necessarily remain in the percentile grades in which, at some time during their period of growth, they may happen to be found.*

FIG. 3.

Weight.—Percentile and Individual Curves Compared.



Continuous lines: normal, 75, 50 and 25 per cent.
Broken lines: individual, 75 and 25 per cent.

As, however, this question seems to be one of the greatest importance, and inasmuch as a definite settlement of all doubts in regard to this matter would be looked upon as a positive advance of our ideas of growth, we have attempted to enter a little more into the details of the matter.

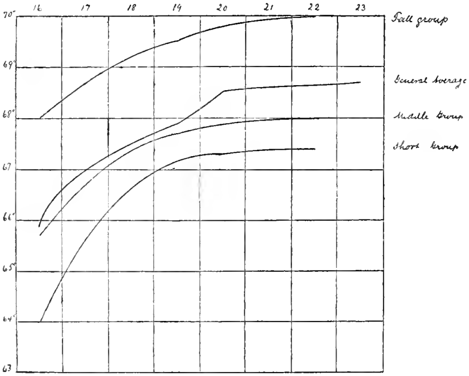
We began by making a somewhat larger collection of individual and continuous records. By allowing a broader limit than a certain percentile grade to begin with, we have succeeded in accumulating the data exhibited in the three Tables XIV, XV and XVI, and have divided them into three groups for reasons which will become more apparent as we proceed. It was perhaps to be expected that growth for tall boys would be found to be different from what it is for short ones, and these tables seem to prove this suspicion to be absolutely correct. When the averages given in these three tables are compared it becomes very evident that there is a well characterized law of growth for each of the three groups, that is to say, it is seen that the short boys grow more rapidly than the tall boys and also more rapidly than middle-sized boys during the period under consideration. Thus we find that the short boys grow 4.2 inches, the middle-sized ones 3.3 inches, and the tall ones only 2.0 inches during a period from 16 to 22 years of age. Previous conditions may perhaps often determine the growth that follows, and the smaller a boy at a certain age during the period of growth the greater will be his chances for growing during the years that follow, while tall boys are very much more apt to have their growth completed earlier than small boys are. Still it seems we cannot deny that present environments and causes also continue to exert an unmistakable influence on growth no matter what the preceding ones may have been.

In order to bring out the difference in the growth of the several groups still more clearly we have made certain selections from the larger tables between definite limits, and have calculated the averages and the probable deviations from different years. The selection was made at every year between the limits indicated on the tables, and then the number of individuals thus selected was carried straight through to the twenty-second year, as shown in Table XVII. It will be noticed by a glance at the table (XVII) that while the averages increase from beginning to end as well as from above downwards during the same years or in the direction from the lowest to highest average, the probable deviations increase only from year to year; but when read from above downwards they very rapidly decrease. In the tall group the averages increase but slightly from year to year in each group and from within the limits indicated; but when read from above downwards they tend to decrease in spite of the limits from which they were started growing steadily higher. The limit of this decrease, however, is soon reached and the averages increase correspondingly. The reason for this behavior in the averages is that the number of those that cease growing increases rapidly and consequently drop out of the succeeding series which contains naturally the tallest and the fewest.

The probable deviations always show a rapid increase between the first two years of every new series; they regularly decrease from above downwards and approach more nearly the average.

FIG 4.

Annual Growth of Average of whole number of obs. compared with that of three selected individual groups.



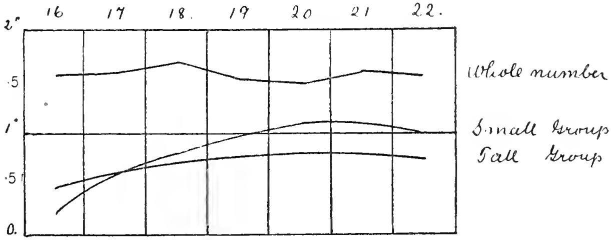
This increase in the probable deviation between the first two years or at the beginning of each series is, no doubt, due to the rapid scattering of the members in each series, and plainly shows that they do not retain the same relation to each other in the next series in which they were contained in the preceding series, and which is additional proof of the fact that *percentile grades do not control growth.*

The average values, showing the absolute annual increase, are not necessarily the most frequent values, as is well known, and consequently we must find out something of the individual growth and their numerical proportion and distribution which produce this average.

For this purpose we have calculated the individual growth between two successive years from our original Tables XIV, XV and XVI and tabulated the results represented in Table XVIII. This table of the individual absolute annual increases in height shows at once the distribution of growth, the most frequent values, and also, in a very striking manner, the number of those who cease to grow and at what age. The difference in the growth between tall and short boys is here brought out very strongly. The figures show as clearly as one could wish that tall boys are much more likely to have completed their growth at an earlier age than short boys, and also that short boys not only grow more rapidly and more extensively than tall boys, but also that they continue to grow up to a later age than do tall boys.

The rapidly increasing numbers at zero, to be seen on Table XVIII, prove conclusively that tall boys have completed their adult stage of development in height at an earlier age than short ones.

FIG. 5.



Probable Deviations compared.

In perfect agreement with this conclusion would seem to be the probable deviation as shown in Fig. 5. In small boys this deviation is seen to rise much higher than in tall ones.

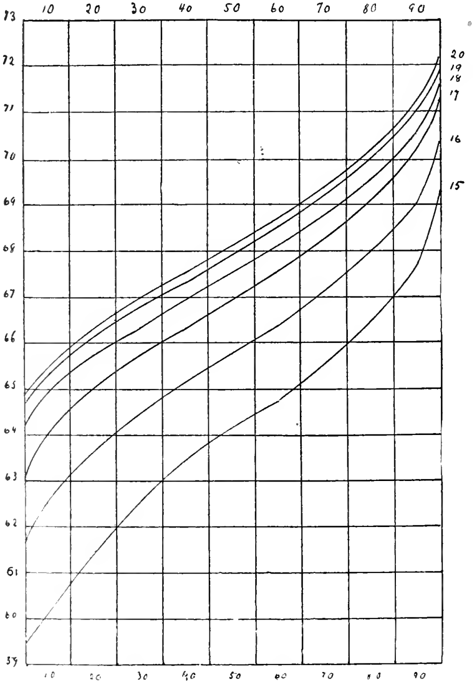
PERCENTILE GRADES IN HEIGHT STANDING, WEIGHT, HEIGHT SITTING, PERINEAL HEIGHT, CIRCUMFERENCE OF CHEST, LUNG CAPACITY, SPAN OF ARMS, WAIST MEASURE, AND RIGHT AND LEFT HAND SQUEEZE.

The percentile grades in these various dimensions are presented in Tables XIX-XXVIII, and those of height standing and weight are also graphically represented in Figs. 6 and 7 respectively. With the help of these tables and plates the percentile rank of any individual in any of the above-mentioned dimensions may be easily and quickly determined.

Supposing, for instance, the percentile rank of a cadet aged 17 years and weighing 134 pounds was desired. A horizontal line is drawn from 134 in the column of weights on the left of the plate to the curve of age 17, and a perpendicular is dropped from the point of intersection to the scale of percentile grades at the bottom of the plate. The perpendicular falls at 75 per cent, and hence the cadet in question is heavier than 75 per cent of the cadets of his age and lighter than the remaining 25 per cent.

FIG. 6.

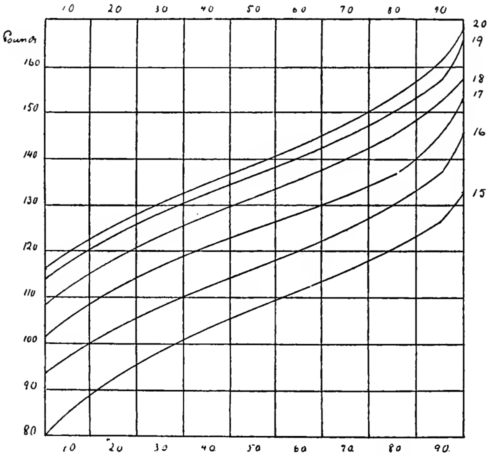
Heights of Naval Cadets.—Percentile Grades.



Likewise we may find the increase at any percentile grade during one or more years by measuring the distance between the curves at that grade and comparing that distance with the pound scale, which will give the number of pounds. In the same plate the gain in weight of the 50 percentile grade cadet during the years of 15 and 18 is 24 pounds, and the gain in weight of the 80th percentile grade cadet during the same period is found to be 25 pounds.

FIG. 7.

Weight of Naval Cadets.—Percentile Grades.



In a somewhat similar manner the percentile rank of any cadet at any age in any dimension included in our tables may be found by a reference to these tables. Their value, therefore, as an aid to the annual examiner of cadets may easily be estimated.

RATE OF GROWTH.

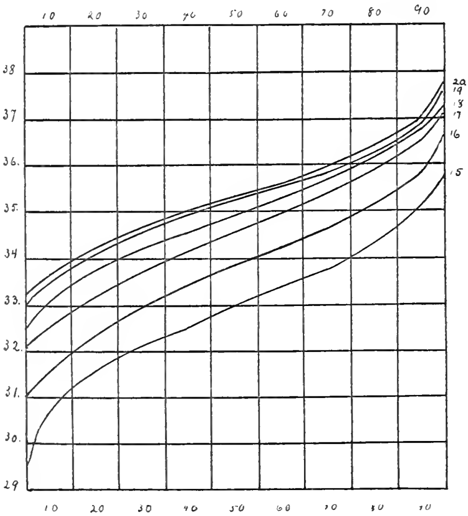
The ten tables XXIX-XXXVIII represent in percentile grades the absolute annual increase in the various dimensions as calculated from the whole number of observations and without regard to whether they are large or small. By absolute annual increase is meant the gain in height or weight during the preceding twelve months, obtained by subtracting the average or median height or weight at, for instance, 18 from that at 19 years.

On account of the unequal distribution of the numbers between the different years, the ages given in the column are not absolutely correct, but the error is so small that it may be neglected here.

It will be noticed that the rate of increase in the various dimensions differs considerably. The subject of the correlation of the different dimensions to one another at the different ages and in individuals of different statures is still to be determined. To settle this question we need a large number of individual records.

FIG. 8.

Perineal Height of Naval Cadets.—Percentile Grades.



As regards weight, we notice a steady decrease in the annual amount of gain from the 15th to the 21st year, which decrease becomes most marked from the 19th year on upwards, and in the highest percentile grades is even negative.

Height once attained is not so easily lost, but weight is easily lost as well as quickly regained.

As to height, the greatest annual increase is noticed to take place between 15 and 16 years of age, the lowest between 18 and 19 years. In some of the highest percentile grades it apparently becomes slightly negative as it does in the weight tables; this is more especially shown between the 21st and 22d years, but also noticeable between the 20th and 21st years. The reason for this negative annual increase is well explained by our Tables XIV, XV and XVI, which show clearly that just about the 21st year our averages are less reliable than they are at other ages, and therefore our annual growth tables do not in the least render improbable the fact that height once attained is rarely if ever lost.

Weight and strength, on the other hand, are easily lost and rapidly regained, and any decrease in these may therefore be easily explained.

Relative Annual Increase.

The ten tables XXXIX-XLVIII represent in percentile grades the relative annual growth in the different dimensions under discussion. Relative annual increase means the increase for any year divided by the average at that year. Thus the relative annual increase in weight at age 18 is the difference between the average weight at 17 and 18 divided by the average weight at 17.

According to Porter (loc. cit.) the relative annual increase gives a truer idea of growth than does the absolute annual increase, because of the latter being entangled with the size of the individual measured. Porter also states that "the absolute annual increase is commonly greater in a big boy than in a small boy,and yet the rate of growth may be the same." This is no doubt true for that period of growth which is covered by the material worked out by him. For a later period, from 15 to 22 years, the rate of growth for big boys is both absolutely and relatively smaller than for short boys. This is not only well shown in our percentile height-curves on Fig. 6, plotted from the whole number of our observations, but also in our individual Tables XIV, XV and XVI, as well as in Fig. 4.

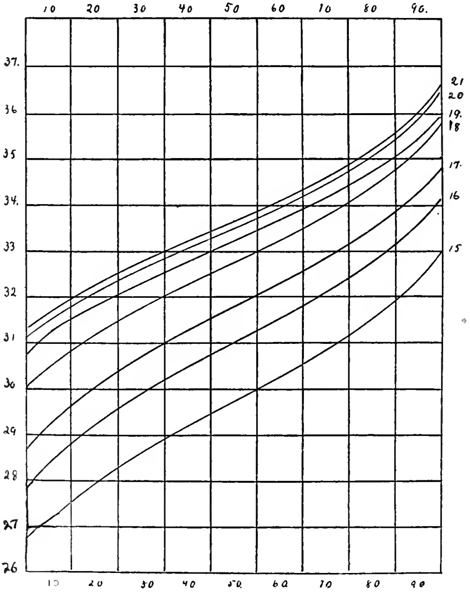
So far as weight is concerned these tables show the same gradual decrease in the annual rate as the height tables. This decrease is here most abruptly marked between 19 and 20, becoming negative with the 21st year.

TABLES XLIX-LVIII.

The material here presented would admit of still further elaboration. The dimensions of correlated parts and their ratios to one another ought to be worked out. The difficulty, however, that presents itself here is the same that was encountered in connection with the rate of growth and its difference between tall and short boys. The facts so far would indicate that, for instance, the ratio that exists between growth in height and chest girth is different for short boys from what it is for tall boys. This work must be done on material admitting of the application of the individualizing method and separately for small, middle-sized and tall individuals, to be of value and conclusive.

FIG. 9.

Chest Girth of Naval Cadets.—Percentile Grades.



The tables XLIX-LVIII, however, will prove useful, admitting, as they do, of ready reference and comparison and containing a great deal of information in a small space.

APPENDIX.

TABLE I.

The observed distribution of the Heights of 842 Naval Cadets aged 18 yrs.

Heights at intervals of one inch.	Number of Observations.
75–76	1
74–75	2
73–74	5
72–73	23
71–72	38
70–71	80
69–70	118
68–69	135
67–68	146
66–67	135
65–66	94
64–65	38
63–64	15
62–63	8
61–62	3
60–61	
59–60	1
Total	..842

TABLE II.

The calculation of the Average Hand-Squeeze (right) of 225 Naval Cadets aged 17 years.

Strength in Pounds.	Number of Observations. (n)	Product (a)
50	2	100
55	3	165
60	15	900
65	18	1170
70	30	2100
75	43	3225
80	40	3200
85	34	2810
90	20	1800
95	11	1045
100	6	600
105	3	315
	Total..$n = 225$	$\Sigma a = 17430$

$$A = \frac{\Sigma a}{n} = \frac{17430}{225} = 75.46 \text{ pounds.}$$

TABLE III.

The calculation of the Probable Deviation (d) from the average weight (125 lbs.) of 722 Naval Cadets aged 17 years.

Weight at intervals of five pounds.	n No. observed.	δ Deviation.	$n\delta$
195–200	1	75	75
170–175	2	50	100
165–170	2	45	90
160–165	6	40	240
155–160	11	35	385
150–155	19	30	570
145–150	24	25	600
140–145	51	20	1020
135–140	59	15	885
130–135	85	10	850
125–130	97	5	485
120–125	97	0	
115–120	82	5	410
110–115	71	10	710
105–110	61	15	915
100–105	35	20	700
95–100	7	25	175
90– 95	9	30	270
85– 90	2	35	70
80– 85	1	40	40
	722		8490

$$d = \pm 0.8453 \frac{8490}{722} = \pm 9.94.$$

TABLE IV.

The theoretical and observed distribution of the Heights of 722 Naval Cadets aged 17 years.

Probable Deviation.	Height at intervals of $\pm 0.5d$.	Theoretical Distribution.	Observed Distribution.
+ 5.0 d	75.00	1	1
+ 4.5 "	74.20	2	2
+ 4.0 "	73.40	4	5
+ 3.5 "	72.60	9	11
+ 3.0 "	71.80	17	18
+ 2.5 "	71.03	30	32
+ 2.0 "	70.20	48	46
+ 1.5 "	69.40	69	70
+ 1.0 "	68.60	87	90
+ 0.5 "	67.80	94	91
0.0 "	67.00		
— 0.5 "	66.20	94	99
— 1.0 "	65.40	87	94
— 1.5 "	64.60	69	72
— 2.0 "	63.80	48	48
— 2.5 "	62.97	30	14
— 3.0 "	62.20	17	16
— 3.5 "	61.40	9	5
— 4.0 "	60.60	4	5
— 4.5 "	59.80	2	2
— 5.0 "	59.00	1	1
		Total..722	722

TABLE V.

Stieda's Table for calculating the number of observations at any distance from the mean or average within the limits: $M + 5d$ and $M - 5d$.

p.	%	p.	%
0.1	5.4	1.8	77.5
0.2	10.7	1.9	80.0
0.3	16.0	2.0	82.3
0.4	21.3	2.1	84.3
0.5	26.4	2.2	86.2
0.6	31.4	2.3	87.9
0.7	36.3	2.4	89.5
0.8	41.1	2.5	90.8
0.9	45.6	2.6	92.1
1.0	50.0	2.7	93.1
1.1	54.2	2.8	94.1
1.2	58.2	2.9	95.0
1.3	61.9	3.0	95.7
1.4	65.5	3.5	98.2
1.5	68.8	4.0	99.3
1.6	71.9	4.5	99.8
1.7	74.8	5.0	99.93

TABLE VI.

The percentile distribution of the Heights of 841 Naval Cadets aged 18 years, according to this method.

Percentile Grades.	Heights.
5	64.56
10	65.00
20	65.90
30	66.70
40	67.01
50	67.66
60	68.54
70	69.00
80	69.58
90	70.55
95	71.52

Table VII.

Probable Error of Average: $E = \pm \frac{d}{\sqrt{n}}$, where e = probable error.
d = probable deviation.
n = number of observations.

Dimensions.	Unit of Measurement.	15	16	17	18	19	20	21	22	23
		Age at nearest Birthday and Probable Error.								
Weight, (nude).........	pounds.	0.922	0.531	0.370	0.400	0.360	0.371	0.456	0.500	0 768
Height, standing.......	inches.	0.136	0.080	0.059	0.057	0.054	0.060	0.071	0.086	0.099
Height, sitting.........	inches.	0.088	0.048	0.032	0.027	0.035	0.027	0.024	0.040	0.036
Height, perineal........	inches.	0.131	0.054	0.045	0.040	0.031	0.038	0.076	0.062	0.073
Chest circumference....	inches.	0.123	0.066	0.044	0.043	0.038	0.048	0.052	0.065	0.079
Lung capacity..........	cb. inches.	2.306	1.091	0.820	0.752	0.642	0.834	0.940	1.150	1.125
Waist circumference....	inches.	0.095	0.052	0.042	0.044	0.044	0.052	0.062	0.070	0.093
Span of Arms...........	inches.	0.130	0.091	0.064	0.060	0.062	0.072	0.076	0.108	0.093
Vision, R. E............	feet.	0.270		0.103	0.108	0.120	0.163	0.103	0.163	0.243
Vision, L. E............	feet.	0.231	0.132	0.111	0.108	0.115	0.133	0.127	0.172	0.233
Hearing, R. Ear........	feet.		0.069	0.050	0.058	0.054	0.100	0.076	0.247	0.238
Hearing, L. Ear........	feet.			0.036	0.036	0.027	0.073	0.110	0.210	0.234
Squeeze, R. H..........	pounds.	0.800	0.367	0.273	0.245	0.274	0.316	0.365	0.449	0.421
Squeeze, L. H.....	pounds.	0.790	0.367	0.274	0.250	0.278	0.322	0.327	0.463	0.466

Table VIII.

Probable Deviation (d) from the average: $d = \pm 0.8453 \frac{\Sigma \delta}{n}$, where δ = Deviation of average.
$\Sigma \delta$ = Sum of individual deviations.
n = Total number of observations.

Dimensions.	Unit of Measure.	15	16	17	18	19	20	21	22	23
		Age at nearest Birthday and Probable Deviation.								
Weight................	kilos.	4.808	4.790	4.508	5.116	4.472	4.277	4.599	4.114	5.357
	pounds.	10.6	10 56	9.94	11.28	9.86	9.43	10.14	9.07	11.81
Height, standing	c. m.	4.97	3.96	4.03	4.20	3.81	3.81	4.01	3.96	3.83
	inches.	1.96	1.56	1.59	1.68	1.50	1.50	1.58	1.56	1.51
Height, sitting	c. m.	2.56	2.43	2.18	2.05	2.49	1.77	1.37	1.88	1.44
	inches.	1.01	0.96	0.86	0.81	0.98	0.70	0.54	0.74	0.57
Height, perineal	c. m.	3.83	3.27	3.17	3.09	2.18	2.49	4.24	2.89	2.84
	inches.	1.51	1.29	1.25	1.22	0.86	0.98	1.67	1.14	1.12
Circumference Chest....	c. m.	3.60	3.37	3.12	3.10	2.64	3.09	2.94	2.99	3.04
	inches.	1.42	1.33	1.23	1.26	1.04	1.22	1.16	1.18	1.20
Lung capacity..	cb. c. m.	427.	355.	360.	373.	320.	376.	330.	330.	312.
	cb. inches.	26.1	21.69	22.0	22.87	19.6	21.19	20.84	20.83	19.05
Circumference Waist....	c. m.	2.76	2.61	2.87	3.30	3.07	3.37	3.50	3.25	3.60
	inches.	1.09	1.03	1.13	1.30	1.21	1.33	1.38	1.28	1.42
Span of Arms....... ...	c. m.	2.99	4.59	4.41	4.44	4.36	4.69	4.26	5.02	3.60
	inches.	1.18	1.81	1.74	1.75	1.72	1.85	1.68	1.98	1.42
Vision, R. E............	meter.	.917	.183	.847	.956	1.002	1.261	1.106	.927	1.130
	feet.	3.09	0.6	2.78	3.14	3.29	4.14	3.63	2.95	3.71
Vision, L. E	meter.	.811	.799	.914	.950	.980	1.029	.857	.947	1.081
	feet.	2.66	2.62	3.0	3.12	3.21	3.38	2.81	3.12	3.55
Hearing, R. Ear........	meter.		.420	.411	.515	.463	.771	.515	1.365	1.106
	feet.	0.0	1.38	1.35	1.69	1.52	2.53	1.69	4.48	3.63
Hearing, L. Ear	meter.			.298	.317	.231	.564	.741	1.161	1.181
	feet.	0 0	0.0	0.98	1.04	0.76	1.85	2.43	3.81	3.88
Squeeze, R. H..........	kilos.	4.136	3.311	3.325	3.225	3.411	3.643	3.679	3.681	2.912
	pounds.	9.12	7.30	7.33	7.11	7.52	8.03	8.11	8.14	6.42
Squeeze, L. H....	kilos.	4.136	3.316	3.370	3.273	3.370	3.715	3.293	3.810	3.220
	pounds.	9.06	7.31	7.43	7.22	7.43	8.19	7.26	8.40	7.10

Table IX.

Values of the Averages in the following dimensions.

Age at nearest Birthday.	No. of Observations.	Weight in kilos., pounds.	Height, standing, c.m., inches.	Height, sitting, c.m., inches.	Height, perineal, c.m., inches.	Circumference of Chest, c.m., inches.	Lung capacity, litres, cb. inch.	Waist, c.m., inches.	Span of Arms, c.m., inches.	Vision, R. E. metres, feet.	Vision, L. E. metres, feet.	Hearing, R. Ear. metres, feet.	Hearing, L. Ear. metres, feet.	Squeeze. R. H. kilos, lbs.	Squeeze. L. H. kilos, lbs.
15	132	48.53	162.052	84.58	81.28	77.47	2.998	63.75	162.30	7.314	7.314	12.192	12.192	27.66	27.21
		107.	63.8	33.3	32.0	30.5	183	25.09	63.9	24.0	24.0	40.0	40.0	61.0	60.
16	395	53.01	167.456	86.48	83.82	80.51	3.293	66.04	170.94	7.332	7.559	11.978	12.192	32.43	31.75
		118.	65.93	34.5	33.2	31.67	201	26.0	67.33	24.6	24.8	39.3	40.0	71.5	70.
17	722	56.70	170.30	88.90	86.36	82.55	3.555	69.59	172.72	7.742	7.620	11.887	12.009	35.127	34.74
		125.	67.05	35.0	34.0	32.5	217	27.36	68.0	25.4	25.0	39.0	39.4	77.47	76.6
18	841	60.55	170.710	90.79	87.36	85.09	3.702	70.80	175.84	7.711	7.528	11.826	11 978	36.74	36.28
		133.4	67.29	35.75	34.6	33.46	226	27.9	69.25	25.3	24.7	38.8	39.3	81.0	80.
19	750	63.36	172.466	91.56	91.8	88.90	3.932	72.61	178.05	7.711	7.681	11.887	12.039	38.55	37.64
		139.7	67.90	36.50	35.9	35.0	240	28.6	70.12	25.3	25.24	39.0	39.5	85.0	83.
20	645	64.05	174.117	89.10	88.90	87.12	3.915	72.64	178.05	7.345	7.925	11.643	11.826	39.46	38.55
		141.2	68.55	35.77	35.0	34.3	239	28.62	70.1	24.1	26.0	38.2	38.8	87.0	85.
21	493	63.40	174.224	91.44	86.36	87.12	3.948	72.89	179.83	7.437	7.620	11.887	11.582	30.91	39.64
		140.	68.6	36.0	34.0	34.3	241	28.68	70.67	24.38	25.0	39.0	38.0	88.0	87.4
22	328	64.09	173.863	91.44	88.90	87.20	4.030	73.15	178.30	7.498	7.406	11.217	11.338	39.23	38.91
		141.3	68.45	36.0	35.0	34.35	246	28.8	70.2	24.6	24.34	36.8	37.2	86.5	85.8
23	232	65.31	174.294	91.44	88.90	88.39	3.964	74.16	180.34	6.888	7.010	11.427	11.368	39.28	38.42
		144.0	68.62	36.0	35.0	34.8	242	29.2	71.0	22.6	23.0	37.5	37.3	86.6	84.7

TABLE X.
Median Values in same dimensions as Table IX.

Age at nearest Birthday.	No. of Observations.	Weight.	Height, standing.	Height, sitting.	Height, perineal.	Circumference of Chest.	Lung capacity.	Waist Circumference.	Span of Arms.	Squeeze, R. H.	Squeeze, L. H.
15	131	49.216 108.5	163.29 64.290		84.12 33.125	76.07 29.952	2.920 178.2	63.70 25.12	163.83 64.50	27.21 60.0	25.58 56.4
16	395	53.025 116.9	167.13 65.805	85.34 33.500	85.92 33.830	78.99 31.101	3.170 193.5	65.45 25.77	169.67 66.80	30.84 68.0	29.48 65.
17	722	56.610 124.8	170.18 67.000	86.81 34.180	87.88 34.600	81.25 31.895	3.421 208.8	67.18 26.45	172.46 67.90	34.10 75.2	33.33 73.5
18	841	59.780 131.8	171.78 67.633	87.96 34.630	88.90 35.007	83.00 32.685	3.588 219.0	69.13 27.22	174.11 68.55	35.14 77.5	34.01 75.0
19	750	62.14 137.0	171.83 67.651	89.07 35.055	89.50 35.243	84.45 33.250	3.736 228.3	70.10 27.60	175.33 69.03	37.19 82.0	36.96 81.5
20	645	62.823 138.5	173.35 68.252	89.53 35.254	89.68 35.310	85.29 33.588	3.818 233.2	71.06 27.98	176.27 69.40	38.00 83.8	37.19 82.0
21	493	63.004 138.9	173.25 68.215	90.01 35.445	89.76 35.340	85.47 33.656	3.801 232.2	70.33 27.69	177.62 69.93	38.91 85.8	38.32 84.5
22	328	62.914 138.7	173.60 68.352	89.71 35.320	90.14 35.492	85.77 33.776	3.883 237.9	70.63 27.81	176.78 69.60	38.55 85.0	38.00 83.8
23	232	62 732 138.3	174.04 68.522	89.73 35.333	90.55 35.654	86.28 33.873	3.872 236.3	70.84 27.89	174.62 69.93	40.37 89.0	38.55 85.0

TABLE XI.
Median minus Average Values.

Dimensions.	Unit of Measurement.	Ages at nearest Birthday and Median minus Average Values.								
		15	16	17	18	19	20	21	22	23
Weight.................	pounds.	+ 1.5	— 1.1	— 0.2	— 1.5	— 2.7	— 2.7	— 1.1	— 2.6	— 5.7
Height, standing	inches.	+ 0.490	— 0.125	— 0.05	+ 0.343	— 0.249	— 0.298	— 0.385	— 0.098	— 0.098
Height, sitting..........	inches.		— 1.000	— 0.820	— 1.120	— 1.445	— 0.516	— 0.555	— 0.680	— 0.667
Height, perineal...... .	inches.	+ 1.125	+ 0.630	+ 0.600	+ 0.407	— 0.657	+ 0.310	+ 1.340	+ 0.492	+ 0.645
Chest circumference....	cb. inches.	— 0.548	— 0.569	— 0.605	— 0.775	— 1.750	— 0.712	— 0.644	— 0.574	— 0.927
Lung capacity.........	cb. inches.	— 4.8	— 7.5	— 8.2	— 7.0	— 11.7	— 5.8	— 8.8	— 8.1	— 5.7
Waist circumference....	inches.	+ 0.03	— 0.23	— 0.97	— 0.68	— 1.00	— 0.64	— 0.99	— 0.99	— 1.31
Span of Arms...........	inches.	+ 0.60	— 0.53	— 0.10	— 0.70	— 1.09	— 0.70	— 0.74	— 0.60	— 1.07
Squeeze, R. H....	pounds.	— 1.0	— 3.5	— 2.27	— 3.5	— 3.0	— 3.2	— 2.2	— 1.5	+ 2.4
Squeeze, L. H..........	pounds.	— 3.6	— 5.0	— 3.1	— 5.0	— 1.5	— 3.0	— 2.9	— 2.0	+ 0.3

TABLE XII.
Showing Annual Growth of different Nationalities.

Ages.	Beyer, c. m.	Bowditch, c. m.	Kotelmann, c. m.	Roberts, c. m.	Erismann, c. m.	Porter, c. m.	
						Av.	Mean.
13–14		6.80	5.79	5.4	3.48	5.67	5.57
14–15	2.54	6.10	5.31	5.1	5.45	6.32	6.39
15–16	5.41	6.90	7.46	5.6	6.53	5.37	6.02
16–17	2.84	2.10	5.25	6.7	5.38	4.86	4.73
17–18	0.60	1.60	1.49	3.9	3.19	5.28	4.50
18–19	1.54	1.40		1.9	1.80		
19–20	1.90			1.8	0.80		
20–21	.12						
21–22	.38						
22–23	.43						

TABLE XIII.
Comparison of Normal * with Individual Records.
I.—Height.

Percentile Grades.	Ages at nearest Birthday.						
	15	16	17	18	19	20	21†
Normal..... ...75	66.20	67.61	68.70	69.29	69.51	69.86	69.83
Individual......75	66.10	67.45	68.25	68.76	69.10	69.15	69.80
Normal.........50	64.29	65.85	67.00	67.63	67.65	68.25	68.21
Individual 25	62.20	64.44	65.62	66.70	66.65	67.62	68.07
Normal.........25	62.05	64.14	65.50	66.18	66.54	66.75	68.74
II.—Weight.							
Individual 75	117.0	129.3	138.0	144.0	148.0	150.0	152.0
Normal 75	118.5	127.8	135.0	143.0	147.5	149.6	149.9
Normal. 50	108.5	116.9	124.8	131.8	137.0	138.5	138.9
Individual .... .25	95.5	107.5	122.0	130.0	130.3	137.0	134.4
Normal.........25	95.9	106.2	114.4	121.9	127.1	128.	129.3

* Number smaller than under the preceding years, especially in individual 75 percentile grade, and therefore this grade is not plotted.

† Refers to the averages derived from the whole number of observations, expressed here in percentile grades.

TABLE XIV.

Individual and Continuous Measurements in Height, Standing. Tallest Group.

No.	Inches at the following years.						
	16	17	18	19	20	21	22
1	68.4	70.0	70.5	71.0	71.1		71.0
2	68.0	69.3	69.5	69.5	69.5		69.6
3	67.4	68.0	68.6	68.3	68.3		68.3
4	69.0	69.7	70.4	70.4	70.5		70 5
5	68.0	68.5	68.7	69.3	69.4		
6	67.4	68.0	68.2	68.3	68.3		68.5
7	68.2	68.6	68.7	69.0	69.1		69.1
8	68.5	69 2	69.3	69.5		69.7	
9	68.5	69.2	69.4	69.2	69.2		69.5
10	67.2	67.6	68.0	68.0	68.1		68.0
11	67.2	67.2	67.5	68.0			
12	68.0	68.6	69.0	69.1	69.2		69.3
13		68.0	68.4	68.6	68.7	68.7	68.7
14		66.7	67.1	67.4	67.4	67.4	67.4
15	67.2	68.3	69.3	69.5	69.6	70.1	70.2
16	68.2	68.6	69.0	69.2	69.4		69.4
17	69.0	70.2	71.0	71.3	71.5		71.4
18	68.7	69.3	69.7	69.7	69.7		69.7
19	67.2	68.1	68.1	68.3	68.2		68.4
20		67.0	67.2	67.5	67.7		67.6
21	68.6	69.4	69.4	70.0	70.1		70.1
22	69.0	69.2	69.2	69.2	69.2		69.2
23	67.0	68.1	68.5	68.7	69.0		69.1
24		66.3	69.4	70.1	70.4	70.4	70.5
25	68.2	69.4	71.0	71.4			71.4
26	67.7	68.1	68.2	68.3		68.4	
27	69.4	70.4	71.2	71.2	71.5		71.6
28	67.4	68.4	68.4	69.0	69.4		70.0
29	68.2	69.4	70.2	71.2	71.2		71.2
30	69.0	69.0	69.0	69.0	69.5		69.4
31	67.0	68.3	68.7	69.0	69.1		69.1
32	67.0	68.0	68.6	68.6	69.0		69.2
33	67.2	67.4	68.0	68.6	68.6		68.6
34	68.3	69.5	70.7	71.1	71.2		71.2
35	69.2	69.3	69.7	70.2	70.4		70.4
36	68.0	68.5	69.0	69.0	69.0		69.1
37	67.0			72.4	73.4	73.4	73.2
38	68.5	69.2	69.2	69.4	69.7	70.0	70.1
39	68.0	69.5	71.0	72.0	72.1		
40	67.4	68.1	68.4	68.4	68.6		68.6
41	68.6	70.3	70.5	71.4	72.2		72.4
42	68.5	69.4	69.4	69.4	69.6		70.0
43	68.2	69.2	69.5	70.0	70.2		70.4
44	68.0	69 4	69.7	70.2	70.4		70.2
45	67.6	69.2	70.3	70.6	70.4		70.7
46	67.0	67.2	68.0	68.0	68.1		68.0
47	69.0	70.3	70.4	70.4	70.4		70.6
48	68.4	69.1	69.6	69.7	69.6		69.6
49	67.5	68.2	68.2	68.6	68.7		69.0
50	68.3	69 2	70.0	70.0	70.5		71.0
51	68.0	69.0	70.0	70.0	70.3		70.2
52	67.5	67.6	68.2	68.2	68.5		
53	67.1	67.6	67.6	67.6	67.7		68.4
54	67.4	68.2	68.7	69.4	69.4		69.6
55	67.6	68.3	69.2	69.3	69.6		69.6
56	67.0	67.4	67.7	68.1			68.1
57	67.2	67.6	67.7	68.1	68.4		68.4
58	68.2	69.2	69.6	70.0	70.2		70.2
59	67.2	68.2	69.1	69.7	69.7		70.2
60	68.0	68.5	69.3	69.3	69.6		70.0
61	67.2	68.3	69.0	69.3	69.3		69.4
62	69.0	69.6	70.3	70.3	70.6		70.6
63	68.0			71.2	71.2	71.2	71.7
Av's.	68.0	68.7	69.2	69.5	69.8		70.0
$\pm d=$	0.49	0.62	0.68	0.76	0.79		0.75

Fractions in columns are eighths; the averages and deviation represented in inches and tenths.

TABLE XV.

Individual and Continuous Measurements in Height, Standing. Middle-sized Group.

No.	Inches at the following years.						
	16	17	18	19	20	21	22
1	65.4	66.1	66.7	67.1	67.3		
2	66.0	67.0	67.3	67.6	67.5	67.5	
3	66.0	68.4	70.7	72.0	72.5		72.5
4		66.4	66.6	66.6	66.6	66.6	67.0
5	66.0	67.0	67.4	67.4	68.		68.1
6		67.0	67.2	67.2	67.5	67.6	67.6
7		65.1	65.4	65.7	65.7	65.5	
8	65.6	68.1	69.0	69.7	69.7		
9		66.2	67.1	68.2	68.6	68.7	68.6
10		66.2	67.1	68.2	68.6	68.7	68.6
11	65.3	66.2	66.5	66.6	67.0	67.0	
12	65.5	66.3	66.5	66.5	66.6		66.6
13	66.2	67.5	68.2	68.5	68.2		68.5
14		65.2	65.5	65.6	65.7	65.7	65.7
15	65.0	66.0	66.2	66.3	66.3		66.3
16	66.0	67.0	67.2	67.6	67.7		67 7
17	66.5	67.4	68.2	68.2	68.6		
18	65.1	65.7	66.4	66.4	66.4		66.4
19	65.0	65.6	66.6	66.6	66.6		66.6
20	66.0	66.4	66.6	66.6	66.6		66.6
21	66.4	67.0	67.5	68.0	68.0		68.0
22	66.4	67.0	67.3	67.5	67.4		67.4
23	66.2	68.0	68.6	69.0	69.0		69.0
24	66.1	67.3	68.1	69.0	69.0		69.0
25	66.1	66.5	67.0	67.0	67.0		67.2
26	65.1	65.4	65.4	65.4	65.5		67.5
27	66.3	67.3	67.5	67.4		67.5	
28	65.2	65.5	66.5	67.0	67.6		
29		65.0	66.4	67.2	67.3	67.5	67.5
30	66.1	67.5	68.6	68.7	68.7		69.0
31	65.2	65.5	66.5	67.0	67.6		
32	65.0	66 4	67.2	67.3	67.5		67.5
33	66.7	67.5	68.6	68.7	68.7		69.0
34		66.0	68.0	68.4	68.6	69.	69.4
35		66.6	68.0	68.4	68.4		70.0
36	65.2	66.0	67.0	67.0	67.3		67.3
37	66.1	67.7	69.2	70.0	70.2		
38	65.0	65.2	65.4	65.4	65.4		65.4
39	65.3	65.7	66.2	66.2	66.2		66.4
40	65.4	67.1	67.4	68.0	68.0		68.0
41	65.1	67.0	67.4	67.4			
42	66.7	67.2	67.2	67.2	67.5		
43	65.5	66.5	67.2	67.2		67.3	
44	65.4	67.0	67.6	68.0	68.4		68.4
45	65.4	67.0	67.4	68.1	68.5		68.5
46	65.2	66.2	67.2	67.2	67.5		
47	65.1	66.0	66.2	66.3	66.4		66.5
48	65.4	67.0	69.0	69.5	69.7		69.6
49	66.0	67.3	68.7	69.6	69.7		69.6
50	65.4	68.4	69.0	69.3	69.4	69.4	69.4
51	66.2	66.4	67.3	67.3		67.4	
52	66.2	66.4	67.4	67.4	67.4		
53	66.6	68.2	68.4	69.0	69.0		69.0
54	66.5	67.1	67.1	67.1	67.1		67.4
55	65.3	66.4	67.0	67.3	67.4	67.4	67.5
56	65.6	67.0	67.4	68.0	68.2	68.1	68.
57	65.2	65.6	66.0	66.5	66.7	67.0	67.0
58	66.4	67 4	67.7	68.1	68.4		68.5
59	65.3	66.4	67.2	68.0	68.2		68.5
60	66.1	67.3	67.7	67.4	67.2		67.3
61	66.6	67.2	68.5	68.5	68.7		69.
62	66.4	68.2	69.0	69.6	70.2		70.4
63	65.2	66.0	67.0	67.0	67.2		67.3
64	65.2	67.0	68.0	68.3	68.3		68.4
65	65.6	66.4	66.6	66.7		66.7	
66	65.4		67.0	67.0	67.2		67.2
67	65.6	65.6	65.6	66.2	66.0		66.2
68	65.0	67.0	67.5	68.0	68.0	68.0	68.2
69	66.4	67.2	68.3	68.7	69.2	69.4	69.4
70	65.5	66.2	67.1	67.0		67.2	
71	65.3	66.7	67.6	68.2	68.3	68.6	68.6
Av's.	65.7	66.7	67.4	67.7	67.9		68.0
$\pm d=$	0.32	0.54	0.55	0.77	0.86		0.90

TABLE XVI.

Individual Continuous Measurements in Height, Standing. Short Group.

No.	16	17	18	19	20	21	22	No.	16	17	18	19	20	21	22
	Inches at the following years.														
1	62.½	65.0	67.6	69.5	70.2		70.6	28	60.4		64.2	65.2	66.7	67.0	67.0
2	63.7	65.2	67.0	67.7	68.2		68.2	29	62.6	63.5	64.4	65.0			
3	64.4	65.3	65.7	66.1	66.2		66.2	30	63.2	64.4	65.7	66.2	66.5		66.5
4	64.4	67.2	67.6	68.2	68.3		68.4	31	62.4	64.5	66.6	67.2	67.4		67.5
5	63.7	65.2	66.2	66.5	66.6		66.7	32	64.2		66.5	67.4	67.7		68.0
6	64.2	67.1	68.6	69.5	69.5		70.1	33	62.2		65.2	65.2	65.6		66.0
7	63.0	64.0	64.4	65.0	65.2		65.4	34	63.0	65.2	66.0	66.3	66.6		
8	64.0	66.2	68.5	70.0	70.4			35	62.1	64.6	65.6	66.1	66.4		67.0
9	64.0	65.0	65.4	66.0	66.2		67.4	36	64.0	64.5	65.3	65.4	66.0		66.0
10	64.6	65.7	66.6	67.3	67.4		67.5	37	62.7	65.2	66.4	66.6		67.0	
11	63.2	65.0	66.7	67.5	68.0		68.1	38	61.0	62.1	65.0	67.3	68.5		69.1
12	64.0	65.6	67.5	68.2	68.5		68.4	39	65.1	67.7	69.1	69.5		69.7	
13	64.1	65.6	67.5	68.2	68.5		68.4	40	63.0	64.2	65.2	65.3	65.6		66.
14	63.7	64.3	64.3	64.7	64.7		64.6	41	64.2	65.0	66.0	66.4	66.3		66.6
15	64.4	66.4	67.6	68.1	68.4		68.4	42	62.5	65.4	68.4	69.7	69.7		70.5
16	64.4	65.1	65.3	65.6	66.1		66.4	43	64.0	66.1	67.2	68.0			
17	64.3	65.6	66.6	67.1	67.1		67.2	44	62.0	63.3	64.5	65.2	65.2		65.3
18	61.0	62.7	64.4	65.2	66.1		66.3	45	63.5	65.2	66.6	67.4	67.6	67.6	67.6
19	61.3	63.5	65.0	65.5	65.6		65.7	46	64.5	64.5	64.7	64.7	65.1		65.2
20	63.6	64.5	65.0	65.0	65.3		65.7	47	61.0	63.0	65.0	65.6	66.0		66.0
21	63.2	65.6	65.7	65.7		66.0		48	62.2	65.2	67.0	67.4	67.7		68.0
22	63.2	65.4	66.2	66.2		66.6		49	64.1	65.2	66.1	67.2	67.3		67.5
23	64.3	65.6	66.6	67.1	67.3			50	63.0	64.4	68.0	69.0	69.3		69.4
24	61.2	63.0	66.6	68.0	69.0	69.6	70.4	51	63.1	66.2	67.0	68.0	68.3	68.2	68.6
25	64.0	65.5	67.0	67.1		67.1		52	62.4	65.3	66.6	68.5	69.2		69.6
26	63.2	64.2	64.7	64.5	64.6	64.7	65.1	Av's..	63.3	65.0	66.3	67.0	67.3		67.5
27	63.4		67.7	68.1	68.1		68.6	±*d*=	0.13	0.61	0.90	1.06	1.07		1.07

TABLE XVII.

Averages and Probable Deviations calculated from certain limited measurements and from different years.

a. Small Group.

Inches.	16 years.	17 years.	18 years.	19 years.	20 years.	22 years.
63.5 — 64.7″ at	64.0 ± 0.2	65.6 ± 0.6	66.7 ± 0.8	67.2 ± 1.0	67.3 ± 1.1	67.4 ± 1.0
65.0 — 66.5″ at		65.6 ± 0.4	67. ± 0.6	67.4 ± 0.8	67.6 ± 0.7	67.6 ± 0.6
66.0 — 67.5″ at			67.0 ± 0.4	67.4 ± 0.4	67.6 ± 0.5	68.0 ± 0.5
67.0 — 68.5″ at				67.5 ± 0.35	68.0 ± 0.45	68.1 ± 0.45
68.0 — 69.5″ at					68.5 ± 0.3	68.7 ± 0.40
68.5 — 70.1						69.3 ± 0.42

b. Tall Group.

Inches.	16 years.	17 years.	18 years.	19 years.	20 years.	22 years.
67.0 — 69.″ at	68.0 ± 0.49	68.7 ± 0.62	69.2 ± 0.68	60.5 ± 0.76	69.8 ± 0.79	70.0 ± 0.75
67.5 — 69.5 at		68.4 ± 0.56	69.2 ± 0.64	69.4 ± 0.74	69.6 ± 0.67	69.7 ± 0.62
68. — 70. at			69.3 ± 0.49	69.2 ± 0.56	69.4 ± 0.55	69.7 ± 0.54
68.5 — 70.5 at				69.4 ± 0.40	69.6 ± 0.42	69.7 ± 0.44
69.0 — 71.0 at					69.7 ± 0.40	69.8 ± 0.42
69.5 — 71.0 at						70.0 + 0.26

TABLE XVIII.

Individual Increases in Height.

Inches.	*a.* Short Group. Years. 16–17	17–18	18–19	19–20	20–22	*b.* Tall Group. Years. 16–17	17–18	18–19	19–20	20–22
.6		1.								
.5										
.4		1.								
.3										
.2										
.1	1.									
3	1.	1.								
.7	3.	1.								
.6	2.	1.								
.5	1.									
.4	2.									
.3	1.	1.	1.							
.2	4.									
.1	2.									
2	2.	1.								
.7	1.	3.	2.							
.6	3.	2.								
.5	2.	2.		1.		2.				
.4	2.	1.			1.	3.				
.3	5.	4.	2.			3.				
.2	2.	4.	1.		1.	4.	1.			
.1	3.	2.	1.			3.	2.			
1	3.	6.	3.	1.		7.	2.	1.	1.	
.7	3.	4.	3.	1.		4.	2.	1.		
.6	1.	3.	5.		1.	4.	8.	2.	1.	
.5	2.	1.	5.	2.	1.	11.	5.	2.	2.	2.
.4	1.	4.	8.	3.	6.	6.	10.	5.	1.	2.
.3		1.	8.	15.	4.		7.	10.	10.	4.
.2		2.	3.	8.	3.	4.	10.	11.	10.	9.
+ .1		1.	4.	7.	13.	4.	4.	6.	16.	8.
o	1.	1.	5.	6.	8.	2.	9.	21.	13.	19.
− .1				1.	3.				2.	8.
.2			1.						1.	2.
Total No.	48.	48.	52.	45.	42.	57.	60.	61.	57.	54.

TABLE XIX. The Height.

Age at nearest Birthday.	No. of observations.	Values in Inches at the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	131	59.507	60.310	61.563	62.553	63.457	64.290	64.855	65.764	66.653	67.717	69.290
16	395	61.750	62.549	63.714	64.580	65.250	65.805	66.455	67.200	68.020	69.000	70.406
17	722	63.130	64.217	65.165	65.853	66.434	67.000	67.626	68.317	69.100	70.320	71.320
18	841	64.193	65.000	65.886	66.483	67.044	67.633	68.251	68.920	69.665	70.520	71.530
19	750	64.680	65.391	66.250	66.844	67.424	67.651	68.600	69.243	69.786	71.000	71.880
20	645	64.962	65.543	66.413	67.094	67.675	68.252	68.810	69.477	70.253	71.280	72.120
21	493	64.970	65.620	66.433	67.054	67.667	68.215	68.852	69.483	70.180	71.120	72.000
22	328	64.945	65.831	66.580	67.200	67.762	68.352	68.960	69.927	70.632	71.543	72.258
23	232	65.287	65.800	66.580	67.300	68.010	68.522	69.030	69.625	70.307	71.240	72.000

TABLE XX. The Weight.

Age at nearest Birthday.	No. of observations.	Values in Pounds at the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	131	80.0	85.3	93.0	98.8	103.8	108.5	112.6	116.5	120.5	127.3	132.0
16	395	94.0	98.6	103.6	108.9	114.2	116.9	121.4	125.4	130.5	137.1	146.2
17	722	102.4	106.5	112.0	116.9	121.0	124.8	128.5	132.5	137.5	144.3	151.6
18	841	109.2	113.3	120.0	123.9	127.9	131.8	135.9	140.0	146.0	153.6	158.0
19	750	114.3	120.0	124.8	129.5	133.3	137.0	142.1	145.3	149.7	158.0	165.1
20	645	116.0	125.2	126.5	131.2	134.9	138.5	142.5	146.9	152.3	160.9	167.8
21	493	117.7	122.0	127.0	131.6	135.3	138.9	143.0	147.2	152.6	160.7	167.3
22	328	117.2	122.1	128.0	132.1	135.3	138.7	142.9	147.8	153.5	160.0	163.1
23	232	118.0	122.2	126.7	131.0	134.7	138.3	142.2	146.4	151.8	163.8	170.0

TABLE XXI. The Height, Sitting.

Age at nearest Birthday.	No. of observations.	Values in Inches in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15												
16	110	31.050	31.600	32.270	32.692	33.110	33.500	33.893	34.285	34.680	35.150	35.577
17	225	32.008	32.400	33.083	33.460	33.833	34.180	34.500	34.821	35.240	35.800	36.135
18	243	32.915	33.174	33.548	33.921	34.278	34.630	35.000	35.044	35.677	36.074	36.602
19	200	33.050	33.333	33.889	34.307	34.700	35.055	35.333	35.611	35.888	36.462	36.850
20	165	35.185	33.543	34.150	34.562	34.975	35.254	35.528	35.800	36.137	36.707	37.000
21	103	33.643	34.100	34.549	34.995	35.222	35.445	35.670	35.893	36.235	36.683	36.907
22	68	33.266	33.644	34.225	34.675	35.050	35.320	35.592	35.864	36.309	36.927	37.433
23	46	34.018	34.288	34.450	34.737	35.026	35.333	35.640	35.946	36.300	36.646	36.823

TABLE XXII. The Perineal Height.

Age at nearest Birthday.	No. of observations.	Values in Inches in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	90	29.545	31.000	31.644	32.120	32.650	33.125	33.500	33.875	34.461	35.222	35.722
16	235	31.150	31.520	32.368	32.987	33.411	33.830	34.245	34.657	35.118	35.808	36.477
17	409	32.084	32.583	33.287	33.780	34.213	34.600	35.000	35.401	36.121	36.537	37.030
18	490	32.500	33.135	33.800	34.260	34.634	35.007	35.357	35.707	36.110	36.781	37.314
19	454	33.033	33.480	34.150	34.525	34.800	35.243	35.560	35.874	36.331	36.885	37.554
20	395	33.209	33.679	34.245	34.618	35.000	35.310	35.629	36.071	36.440	36.970	37.720
21	318	32.926	33.450	34.180	34.600	35.012	25.340	35.670	36.000	36.483	36.972	37.670
22	212	33.270	33.771	34.348	34.800	35.176	35.492	35.810	36.221	36.779	37.500	37.900
23	160	33.500	34.090	33.576	35.040	35.350	35.654	35.961	36.535	36.700	37.177	37.650

TABLE XXIII.

The Circumference of the Chest midway between Inspiration and Expiration.

Age at nearest Birthday.	No. of observations.	Values in Inches in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	132	26.600	27.262	28.070	28.700	29.300	29.952	30.470	31.063	31.664	32.483	33.000
16	395	27.980	28.464	29.333	30.071	30.584	31.101	31.635	32.000	32.712	33.513	34.150
17	722	28.740	29.170	30.480	31.061	31.478	31.895	32.324	32.751	33.347	34.221	34.843
18	841	30.028	30.588	31.322	31.832	32.275	32.685	33.135	33.715	34.354	35.100	35.813
19	750	30.814	31.300	32.011	32.428	32.844	33.250	33.710	34.184	34.735	35.481	35.944
20	645	31.078	31.500	32.153	32.700	33.165	33.588	34.000	34.489	34.960	35.804	36.576
21	496	31.152	31.580	32.280	32.720	33.270	33.656	34.055	34.546	35.060	35.834	36.680
22	328	31.231	31.744	32.384	32.900	33.345	33.776	34.208	34.640	35.142	36.000	36.873
23	232	31.255	31.900	32.474	33.029	33.451	33.873	34.265	34.646	35.055	35.855	36.822

TABLE XXIV.

The Lung-capacity ascertained by means of the Spirometer.

Age at nearest Birthday.	No. of observations.	Values in Cubic Inches in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	132	117.2	132.0	148.4	156.4	166.2	178.2	190.0	198.9	205.5	219.5	233.5
16	395	143.2	152.1	166.8	176.3	185.9	193.5	199.4	210.7	224.0	237.0	253.5
17	722	156.4	171.0	181.9	192.7	198.8	208.8	216.8	228.5	238.8	252.7	263.1
18	841	170.0	180.0	192.3	203.5	212.5	219.0	227.7	236.0	245.7	260.0	272.2
19	750	181.0	192.3	203.3	213.2	220.8	228.3	235.6	243.4	253.1	268.6	287.0
20	645	185.6	194.3	206.9	215.8	224.0	233.2	242.0	249.6	261.0	277.6	290.7
21	493	185.7	194.6	207.0	219.5	224.1	232.2	240.0	248.3	259.0	277.4	287.5
22	328	194.0	203.4	214.5	222.5	231.1	237.9	245.8	254.6	263.8	286.5	298.5
23	232	194.7	204.0	211.5	221.0	230.0	236.3	245.3	255.1	264.6	276.2	285.5

TABLE XXV.

The Span, in Inches, of the Arms.

Age at nearest Birthday.	No. of observations.	Values in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	33	60.65	61.65	62.52	63.25	64.05	64.50	64.97	65.55	67.48	68.35	68.78
16	110	60.90	63.00	64.54	65.42	66.25	66.80	67.44	68.15	69.00	70.25	71.83
17	225	63.61	64.61	65.74	66.57	67.27	67.90	68.54	69.27	70.24	71.54	72.57
18	243	64.47	65.23	66.16	67.14	67.91	68.55	69.23	69.81	70.80	72.12	73.00
19	200	64.45	65.66	66.90	67.60	68.34	69.03	69.64	70.40	71.35	72.50	73.55
20	165	64.88	66.13	67.15	67.97	68.70	69.40	70.12	71.07	71.82	73.34	73.80
21	103	65.30	67.03	68.12	68.91	69.44	69.93	70.63	71.32	71.96	73.34	74.62
22	68	65.10	66.00	67.20	68.05	68.90	69.60	70.35	71.23	72.28	73.80	74.43
23	46	67.05	67.43	68.60	69.27	69.60	69.93	70.60	71.27	71.85	72.85	73.85

TABLE XXVI.

The Circumference, in Inches, of the Waist.

Age at nearest Birthday.	No. of observations.	Values in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	134	21.67	22.67	23.50	24.09	24.62	25.12	25.53	25.93	26.53	27.60	28.61
16	395	23.23	23.75	24.47	25.06	25.41	25.77	26.18	26.71	27.31	27.97	28.80
17	722	23.84	24.38	25.13	25.57	26.00	26.45	26.90	27.42	27.96	28.78	29.48
18	841	24.21	24.86	25.69	26.28	26.75	27.22	27.70	28.21	28.59	29.68	30.43
19	750	24.33	25.20	26.03	26.60	27.15	27.60	28.05	28.53	29.02	29.82	30.65
20	645	24.68	25.32	26.19	26.83	27.32	27.98	28.26	28.53	29.58	30.66	31.40
21	493	24.58	25.23	26.07	26.66	27.21	27.69	28.21	28.85	29.62	30.54	31.19
22	328	25.09	25.53	26.24	26.76	27.28	27.81	28.35	28.91	29.46	30.25	31.00
23	232	24.87	25.53	26.40	27.03	27.46	27.89	28.48	29.13	29.84	30.85	31.70

TABLE XXVII.

Right Hand Squeeze in Pounds.

Age at nearest Birthday.	No. of observations.	Values at the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	46	38.0	40.6	46.3	53.0	58.6	60.0	64.0	68.0	70.3	79.0	80.0
16	120	51.0	55.5	59.0	62.1	65.2	68.0	70.7	73.5	76.8	81.2	90.0
17	225	57.1	60.7	66.1	70.0	72.5	75.2	78.0	81.0	84.2	89.4	94.0
18	243	62.8	65.7	68.0	70.4	74.5	77.2	80.1	83.1	86.6	91.7	96.8
19	200	65.6	68.8	72.6	75.9	78.8	82.0	85.2	88.1	91.6	97.6	102.5
20	165	66.2	69.7	74.7	77.8	80.3	83.8	86.8	89.8	95.2	99.0	103.0
21	103	67.1	71.0	75.6	79.6	82.7	85.8	89.5	92.7	96.7	102.1	107.0
22	68	66.0	68.4	72.5	77.0	81.6	85.0	87.1	89.2	94.4	98.9	105.0
23	46	68.9	72.0	78.6	83.8	86.7	89.0	92.1	95.5	97.6	99.7	107.1

TABLE XXVIII.

Left Hand Squeeze in Pounds.

Age at nearest Birthday.	No. of observations.	Values in the following Percentile Grades.										
		5	10	20	30	40	50	60	70	80	90	95
15	36	33.0	36.0	43.0	49.6	54.2	56.4	58.0	59.6	64.6	71.0	75.5
16	110	45.0	50.9	55.6	59.0	62.1	65.0	66.7	68.6	72.0	80.0	85.0
17	225	55.0	58.9	64.7	68.6	71.6	73.5	76.1	79.4	82.7	87.5	92.7
18	245	57.5	61.6	66.5	69.0	71.6	75.0	77.6	80.0	84.5	89.2	94.8
19	200	64.4	66.8	70.8	74.4	78.3	81.5	83.1	86.1	89.5	96.3	99.6
20	165	63.3	66.8	71.9	76.0	79.3	82.0	84.6	90.0	94.0	99.4	104.2
21	103	67.7	71.5	75.7	78.8	81.7	84.5	87.3	90.0	93.7	99.7	104.8
22	68	65.2	67.1	72.0	77.0	80.0	83.8	86.8	89.4	94.5	99.4	103.2
23	46	66.5	69.0	77.2	80.4	82.7	85.0	87.3	89.6	92.3	97.2	104.2

TABLE XXIX.
The Absolute Annual Increase in Weight in Pounds.

Age at nearest Birthday.	Values in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15-16	14.0	13.3	10.6	10.1	11.4	8.4	8.8	8.9	10.0	9.8	14.2	11.0
16-17	8.4	7.9	8.4	8.0	6.8	7.9	7.1	7.1	7.0	7.2	5.4	7.0
17-18	6.8	6.8	8.0	7.0	6.9	7.0	7.4	7.5	8.5	9.3	6.4	8.4
18-19	5.1	6.7	4.8	5.6	5.4	5.3	6.2	5.3	3.7	5.4	7.1	6.32
19-20	1.7	5.2	1.7	1.7	1.6	1.5	0.4	1.6	2.6	2.9	2.7	1.5
20-21	1.7	3.2	0.5	0.4	0.4	0.4	0.5	0.3	0.3	—0.2	—0.5	—1.2
21-22	—0.5	0.1	1.0	0.5	0.0	—0.2	—0.1	0.6	0.9	—0.7	—4.2	—1.3
22-23	2.8	0.1	1.3	—1.1	—0.6	—0.4	—0.7	—1.4	—1.7	3.8	6.9	2.7

TABLE XXX.
The Absolute Annual Increase in Height, Standing.

Age at nearest Birthday.	Values in Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15-16	2.243	2.239	1.151	2.027	1.793	1.515	1.570	1.536	1.367	1.283	1.177	2.13
16-17	1.380	1.668	1.451	1.273	1.184	1.195	1.172	1.117	1.080	1.320	0.914	1.12
17-18	1.063	1.283	0.721	0.630	0.610	0.633	0.624	0.603	0.565	0.200	0.210	0.24
18-19	0.487	0.391	0.364	0.361	0.380	0.018	0.349	0.323	0.121	0.480	0.350	0.61
19-20	0.282	0.152	0.163	0.250	0.251	0.601	0.210	0.234	0.467	0.280	0.240	0.65
20-21	0.008	0.077	0.020	—0.040	—0.008	—0.037	0.042	0.006	—0.073	—0.160	—0.120	0.05
21-22	—0.025	0.211	0.147	0.146	0.095	0.137	0.108	0.444	0.452	0.423	0.258	—0.15
22-23	0.342	—0.031	0.000	0.100	0.248	0.170	0.070	—0.302	—0.325	—0.303	—0.258	0.17

TABLE XXXI.
The Absolute Annual Increase in Height, Sitting.

Age at nearest Birthday.	Values in Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
16-17	0.958	0.800	0.813	0.768	0.723	0.680	0.607	0.536	0.560	0.650	0.558	0.50
17-18	0.907	0.774	0.465	0.461	0.445	0.450	0.500	0.223	0.437	0.274	0.467	0.75
18-19	0.135	0.159	0.341	0.386	0.422	0.425	0.333	0.567	0.211	0.388	0.248	0.75
19-20	0.135	0.210	0.261	0.255	0.275	0.199	0.195	0.189	0.249	0.245	0.150	0.73
20-21	0.458	0.557	0.399	0.433	0.247	0.191	0.142	0.093	0.098	—0.024	—0.093	—0.23
21-22	—3.77	—0.456	—0.324	—0.320	—0.172	—0.125	—0.078	—0.029	0.074	0.244	0.526	0.00
22-23	0.752	0.644	0.225	0.062	—0.024	0.013	0.048	0.082	—0.009	—0.281	0.390	0.00

TABLE XXXII.
The Absolute Annual Increase in Perineal Height.

Age at nearest Birthday.	Values in Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15-16	1.605	0.220	0.724	0.867	0.761	0.705	0.745	0.782	0.657	0.586	0.755	1.20
16-17	0.934	1.363	0.919	0.793	0.802	0.770	0.745	0.744	1.003	0.729	0.553	0.80
17-18	0.416	0.552	0.513	0.480	0.421	0.407	0.357	0.306	0.091	0.244	0.284	0.60
18-19	0.533	0.345	0.350	0.265	0.166	0.236	0.203	0.167	0.221	0.104	0.240	1.30
19-20	0.166	0.199	0.095	0.093	0.200	0.067	0.069	0.197	0.109	0.085	0.166	—0.90
20-21	—0.273	—0.229	—0.065	—0.018	0.012	0.030	0.041	—0.071	0.043	0.002	—0.050	—1.00
21-22	0.344	0.321	0.168	0.200	0.164	0.152	0.140	0.221	0.296	0.528	0.230	1.00
22-23	0.220	0.319	0.228	0.240	0.174	0.162	0.151	0.314	—0.079	—0.323	— .025	0.00

TABLE XXXIII.
The Absolute Annual Increase in Circumference of Chest.

Age at nearest Birthday.	Values in Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15-16	1.383	1.202	1.263	1.371	1.284	1.149	1.165	0.937	1.048	1.030	1.150	1.17
16-17	0.757	0.706	1.147	0.990	0.894	0.794	0.689	0.751	0.635	0.708	0.693	0.83
17-18	1.288	1.418	0.942	0.771	0.797	0.790	0.811	0.964	1.007	0.879	0.970	0.94
18-19	0.786	0.712	0.689	0.596	0.569	0.565	0.575	0.469	0.381	0.381	0.131	1.54
19-20	0.264	0.200	0.142	0.272	0.321	0.338	0.290	0.305	0.235	0.323	0.532	—0.70
20-21	0.074	0.080	0.127	0.020	0.105	0.068	0.055	0.057	0.100	0.030	0.104	0.00
21-22	0.079	0.164	0.104	0.180	0.075	0.120	0.153	0.106	0.082	0.166	0.193	0.05
22-23	0.024	0.156	0.090	0.129	0.066	0.097	0.057	0.006	—0.087	—0.145	—0.051	0.45

TABLE XXXIV.
The Absolute Annual Increase in Lung-capacity. (Spirometer.)

Age at nearest Birthday.	Values in Cubic Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15-16	26.0	20.1	18.4	19.9	19.7	15.3	9.4	11.8	18.5	17.5	20.0	18.0
16-17	13.2	18.9	15.1	16.4	12.9	15.3	17.4	17.8	14.8	15.7	9.6	16.0
17-18	14.4	9.0	10.4	10.8	13.7	10.2	10.9	8.5	6.9	7.3	9.1	9.0
18-19	11.0	12.3	11.0	9.7	8.3	9.3	7.9	7.4	7.4	8.6	14.8	14.0
19-20	4.6	2.0	3.6	2.6	3.2	5.9	6.4	6.2	7.9	9.0	3.7	—1.0
20-21	0.1	0.3	0.1	3.7	0.1	0.0	—2.0	—1.3	—2.0	— 1.02	— 3.2	2.0
21-22	8.3	8.8	7.5	2.0	7.0	5.7	5.8	6.3	4.8	19.1	11.0	5.0
22-23	0.7	0.6	3.0	—1.5	—1.1	—1.6	—0.5	0.5	0.8	—10.3	—13.0	—4.0

TABLE XXXV.
The Absolute Annual Increase in Circumference of Waist.

Age at nearest Birthday.	Values in Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	1.56	1.08	0.97	0.97	0.79	0.65	0.65	0.78	0.78	0.37	0.19	0.91
16–17	0.61	0.63	0.66	0.51	0.59	0.68	0.72	0.71	0.65	0.81	0.68	1.36
17–18	0.37	0.48	0.56	0.71	0.75	0.77	0.80	0.79	0.63	0.90	0.95	0.54
18–19	0.12	0.34	0.34	0.32	0.40	0.38	0.35	0.32	0.43	0.14	0.22	0.30
19–20	0.35	0.12	0.16	0.23	0.17	0.38	0.21	0.30	0.56	0.84	0.75	0.02
20–21	−0.10	−0.09	−0.12	−0.17	−0.11	−0.29	−0.05	0.02	0.04	−0.12	−0.21	0.06
21–22	0.51	0.30	0.17	0.10	0.07	0.12	0.14	0.06	−0.16	−0.29	−0.19	0.12
22–23	−0.22	0.00	0.16	0.27	0.18	0.08	0.13	0.22	0.38	0.50	0.70	0.40

TABLE XXXVI.
The Absolute Annual Increase in the Span of Arms.

Age at nearest Birthday.	Values in Inches in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	0.25	1.35	2.02	2.17	2.20	2.30	2.47	2.60	1.52	1.90	3.05	3.43
16–17	2.71	1.61	1.20	1.15	1.02	1.10	1.10	1.12	1.24	1.29	0.74	0.77
17–18	0.86	0.62	0.42	0.67	0.64	0.65	0.69	0.54	0.56	0.58	0.46	1.25
18–19	−0.02	0.43	0.74	0.46	0.43	0.48	0.41	0.59	0.55	0.32	0.55	0.80
19–20	0.43	0.47	0.25	0.37	0.36	0.37	0.48	0.67	0.47	0.84	0.25	−0.02
20–21	0.42	0.90	0.97	0.94	0.74	0.53	0.51	0.25	0.14	0.00	0.82	0.57
21–22	−1.20	−1.03	−0.92	−0.86	−0.54	−0.33	−0.28	−0.09	0.32	0.44	−0.19	−0.47
22–23	2.95	1.43	1.40	1.22	0.70	0.33	0.25	−0.06	−0.43	−0.95	−0.58	−0.80

TABLE XXXVII.
The Absolute Annual Increase in Right Hand Squeeze.

Age at nearest Birthday.	Values in Pounds in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	13.0	14.9	12.7	9.1	6.6	8.0	6.7	5.5	6.5	3.1	10.0	10.50
16–17	6.1	5.2	7.1	7.9	7.3	7.2	7.3	7.5	7.4	7.3	4.0	5.97
17–18	5.7	5.0	1.9	0.4	2.0	2.3	2.1	2.1	2.4	2.3	2.8	3.53
18–19	2.8	3.1	4.6	5.5	4.3	4.5	5.1	5.0	5.0	5.9	5.7	4.00
19–20	0.6	0.9	2.1	1.9	1.5	1.8	1.6	1.7	3.6	1.4	1.2	2.00
20–21	0.9	1.3	0.9	1.8	2.4	2.0	2.7	2.9	1.5	3.1	3.3	1.00
21–22	−1.1	2.6	−3.1	−2.6	−1.1	−0.8	−2.4	−3.5	−2.3	−3.2	−2.0	−1.50
22–23	2.9	3.6	6.1	6.8	5.1	4.0	5.0	6.3	3.2	0.8	2.1	0.10

TABLE XXXVIII.
The Absolute Annual Increase in Left Hand Squeeze.

Age at nearest Birthday.	Values in Pounds in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	12.0	14.9	12.6	9.4	7.9	8.6	8.7	9.0	7.4	9.0	9.5	10.0
16–17	10.0	8.0	9.1	9.6	9.5	8.5	9.4	10.8	10.7	7.5	7.7	6.6
17–18	2.1	2.7	1.8	0.4	0.0	1.5	1.5	0.6	1.8	1.7	2.1	3.4
18–19	7.3	5.2	4.3	5.4	6.7	6.5	5.5	6.1	5.0	7.1	4.8	3.0
19–20	−1.1	0.0	1.1	1.6	1.0	0.5	1.5	3.9	4.5	3.1	4.6	2.0
20–21	4.3	4.7	3.8	2.8	2.4	2.5	2.7	0.0	−0.3	0.3	0.6	2.4
21–22	−2.5	−4.4	−3.7	−1.8	−1.7	−0.7	−0.5	−0.6	0.8	−0.3	−1.6	−1.6
22–23	1.3	1.9	5.2	3.4	2.7	1.2	0.5	0.2	−2.2	−2.2	1.0	−1.1

TABLE XXXIX.
The Relative Annual Increase in Weight. (Pounds.)

Age at nearest Birthday.	Values in Per Cent. in the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	13.1	12.4	10.0	9.4	10.6	8.0	8.2	8.3	9.3	9.2	13.2	10.3
16–17	7.1	6.7	7.1	6.8	5.8	6.7	6.0	6.0	6.0	6.0	4.6	6.0
17–18	5.4	5.4	6.4	5.6	5.5	5.6	6.0	6.0	6.8	7.4	5.1	6.7
18–19	3.8		3.7	4.2	4.0	4.0	4.7	4.0	2.3	4.0	5.3	5.0
19–20	1.2	3.7	1.2	1.2	1.1	1.1	0.3	1.1	1.8	2.1	2.0	1.1
20–21	1.2	2.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	−0.1	−0.3	−0.8
21–22	−0.4	0.1	0.7	0.4	0.0	−0.4	−0.1	0.4	0.6	−0.5	−3.0	−1.0
22–23	2.0	0.1	−0.9	−0.8	−0.4	−0.3	−0.5	−1.0	−1.2	2.7	4.9	2.0

TABLE XL.
The Relative Annual Increase in Height, Standing. (Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	3.51	3.51	1.80	3.17	2.72	2.37	2.41	2.41	2.14	2.01	1.84	3.34
16–17	2.09	2.53	2.20	1.93	1.79	1.81	1.79	1.71	1.64	2.02	1.08	1.70
17–18	1.58	1.91	1.07	0.93	0.91	0.93	0.93	0.90	0.83	0.30	0.31	0.36
18–19	0.72	0.58	0.54	0.53	0.56	0.03	0.52	0.47	0.17	0.72	0.52	0.91
19–20	0.41	0.22	0.24	0.37	0.37	0.88	0.30	0.34	0.68	0.41	0.35	0.95
20–21	0.001	0.01	0.003	−0.058	−0.012	−0.058	0.061	0.008	−0.107	−0.232	−0.175	0.073
21–22	−0.036	0.307	0.214	0.214	0.138	0.200	0.157	0.647	0.647	0.616	0.367	−0.215
22–23	0.500	−0.045	0.000	0.146	0.362	0.248	0.102	−0.441	−0.474	−0.442	−0.377	0.248

TABLE XLI.

The Relative Annual Increase in Height, Sitting. (Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
16–17	2.87	2.40	2.44	2.30	2.17	2.04	1.82	1.61	1.68	1.95	1.95	1.50
17–18	2.60	2.21	1.30	1.30	1.27	1.21	1.43	0.64	1.25	0.78	1.30	2.14
18–19	0.38	0.44	0.95	1.08	1.18	1.18	0.93	1.58	0.59	1.08	0.69	2.10
19–20	0.37	0.60	0.71	0.70	0.75	0.52	0.52	0.50	0.68	0.68	0.41	2.00
20–21	1.28	1.55	1.11	1.21	0.69	0.53	0.39	0.27	0.29	−0.08	−0.27	−0.62
21–22	−1.05	−1.26	−0.90	−0.90	−0.48	−0.35	−0.21	−0.08	0.20	0.68	1.46	0.00
22–23	2.10	1.80	0.62	0.17	−0.07	0.03	0.13	0.23	−0.02	−0.77	1.08	0.00

TABLE XLII.

The Relative Annual Increase in Perineal Height. (Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	5.00	0.70	2.26	2.71	2.30	2.20	2.33	2.44	2.05	1.83	2.36	3.80
16–17	2.81	4.10	2.16	2.38	2.41	2.32	2.24	2.24	3.02	2.20	1.70	2.41
17–18	1.22	1.62	1.51	1.41	1.24	1.20	1.05	0.90	0.30	0.72	0.84	1.77
18–19	1.54	1.00	1.01	0.74	0.48	0.69	0.58	0.47	0.64	0.30	0.70	3.76
19–20	0.46	0.55	0.26	0.26	0.58	0.19	0.19	0.55	0.30	0.24	0.46	−2.50
20–21	−0.40	−0.33	−0.09	−0.027	0.020	0.04	0.103	−0.10	0.06	0.003	−0.07	−1.459
21–22	0.96	0.89	0.47	0.57	0.47	0.42	0.39	0.61	0.82	1.46	0.64	2.77
22–23	0.61	0.88	0.64	0.66	0.50	0.45	0.42	0.90	−0.22	−0.90	−0.89	0.00

TABLE XLIII.

The Relative Annual Increase in Circumference of Chest. (Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	4.54	3.93	4.14	4.50	4.21	3.77	3.82	3.62	3.40	3.37	3.77	3.83
16–17	2.39	2.23	3.62	3.12	2.82	2.50	2.17	2.38	2.01	2.23	2.19	2.62
17–18	3.96	4.36	2.90	2.37	2.45	2.44	2.50	2.97	3.09	2.70	2.97	2.90
18–19	2.34	2.13	2.06	1.78	1.70	1.70	1.72	1.41	1.14	1.14	0.40	4.60
19–20	0.75	0.57	0.40	0.80	0.91	0.96	0.85	0.90	0.67	0.92	1.52	−2.00
20–21	0.21	0.23	0.37	0.06	0.30	0.20	0.16	0.16	0.30	0.09	0.30	0.00
21–22	0.23	0.47	0.30	0.52	0.21	0.36	0.44	0.30	0.23	0.47	0.56	0.02
22–23	0.07	0.45	0.26	0.36	0.19	0.28	0.16	0.01	−0.25	−0.42	−0.15	1.40

TABLE XLIV.

The Relative Annual Increase in Lung Capacity. (Cb. Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	14.2	10.1	11.0	11.0	11.0	8.3	5.1	6.4	10.1	9.5	11.0	10.0
16–17	6.5	7.5	9.4	8.1	6.4	7.6	8.6	8.9	7.3	7.8	4.7	8.0
17–18	6.6	4.8	4.1	5.0	6.3	4.7	5.0	4.0	3.2	3.3	4.2	4.1
18–19	4.8	4.8	5.4	4.3	3.7	4.1	3.5	3.3	3.3	3.8	6.6	6.2
19–20	1.9	1.5	0.8	1.1	1.3	2.5	2.7	2.2	3.3	3.8	1.6	−0.4
20–21	0.04	0.04	0.12	1.60	0.04	0.00	−0.83	−0.54	−0.84	−0.43	−1.34	0.84
21–22	3.40	3.11	3.65	0.83	2.90	2.37	2.37	2.61	2.00	7.39	4.60	2.08
22–23	0.28	−1.22	0.24	−0.60	−0.45	−0.60	−0.20	0.20	0.32	−4.20	−5.29	−1.62
		20 P. G.	10 P. G.									

TABLE XLV.

The Relative Annual Increase in Circumference of Waist. (Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	6.21	4.30	3.86	3.86	3.15	2.35	2.35	3.15	3.50	1.50	0.75	3.63
16–17	2.35	2.42	2.54	2.00	2.27	2.64	2.77	2.77	2.50	3.11	2.64	5.23
17–18	1.34	1.75	2.04	2.59	2.73	2.81	2.92	2.90	2.30	3.28	2.81	2.00
18–19	0.43	1.22	1.22	1.11	1.43	1.36	1.25	1.11	1.54	0.50	0.80	1.08
19–20	1.23	0.42	0.56	0.80	0.59	1.33	0.73	1.50	2.00	3.00	2.62	0.07
20–21	−0.35	−0.31	−0.42	−0.60	−0.39	−1.01	−0.17	0.07	0.14	−0.42	−0.73	0.21
21–22	1.77	1.04	0.60	0.34	0.24	0.42	0.49	0.21	−0.55	−1.01	−0.66	0.41
22–23	−0.76	0.00	0.55	0.93	0.62	0.28	0.45	0.76	1.32	1.73	2.42	1.40

TABLE XLVI.
The Relative Annual Increase in Span of Arms. (Inches.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	0.39	2.11	3.15	3.86	3.58	3.60	3.86	4.10	2.38	2.97	4.76	5.37
16–17	4.04	2.40	1.78	1.71	1.51	1.63	1.63	1.64	1.79	1.80	1.00	1.14
17–18	1.26	0.91	0.61	1.00	0.95	0.95	1.01	0.71	0.72	0.72	0.63	1.83
18–19	—0.02	0.62	1.06	0.66	0.62	0.67	0.61	0.85	0.79	0.46	0.79	1.15
19–20	0.61	0.67	0.35	0.52	0.51	0.52	0.68	0.95	0.67	1.19	0.35	—0.03
20–21	0.60	1.28	1.38	1.34	1.05	0.75	0.74	0.35	0.20	0.00	1.17	0.81
21–22	—1.70	—1.45	—1.30	—1.21	—0.76	—0.46	—0.40	—0.12	0.45	0.62	—0.27	—0.66
22–23	4.20	2.03	2.00	1.73	1.00	0.47	0.35	—0.08	—0.61	—1.35	—0.82	1.14

TABLE XLVII.
The Relative Annual Increase in Right Hand Squeeze. (Pounds.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	21.3	24.4	20.8	15.0	10.8	13.1	11.0	9.0	10.6	5.1	16.4	17.2
16–17	8.5	7.2	10.0	11.0	10.2	10.1	10.2	10.5	10.3	10.2	5.6	8.3
17–18	7.3	6.4	2.4	0.5	2.6	3.00	2.7	2.7	3.1	3.0	3.6	4.5
18–19	3.5	3.8	5.7	6.8	5.3	5.5	6.3	6.2	6.2	7.3	7.0	5.0
19–20	0.7	1.0	2.4	2.2	1.7	2.1	1.8	2.0	4.2	1.6	1.4	2.3
20–21	1.0	1.5	1.0	2.1	2.7	2.3	3.1	3.3	1.7	3.5	3.8	1.1
21–22	—1.2	—3.00	—3.5	—3.0	—1.2	—0.9	—2.7	—4.0	—2.6	—3.6	—2.2	—1.7
22–23	3.3	4.2	7.3	7.8	5.9	4.6	5.8	7.4	3.7	0.9	2.4	0.1

TABLE XLVIII.
The Relative Annual Increase in Left Hand Squeeze. (Pounds.)

Age at nearest Birthday.	Values in Per Cent. at the following Percentile Grades.											
	5	10	20	30	40	50	60	70	80	90	95	Average.
15–16	20.0	25.0	21.0	16.0	13.1	14.3	14.5	15.0	12.3	15.0	15.1	16.6
16–17	14.3	11.4	13.0	13.7	13.5	12.1	13.4	15.4	15.3	10.7	11.0	9.1
17–18	2.7	3.5	2.3	0.5	0.0	2.0	2.0	0.8	2.3	2.2	2.7	4.4
18–19	9.1	6.5	5.4	6.7	8.4	8.1	7.0	7.6	6.2	8.8	6.0	3.8
19–20	—1.3	0.0	1.3	1.9	1.2	0.6	1.8	4.7	5.4	3.8	5.5	2.4
20–21	5.0	5.5	4.4	3.3	2.8	2.9	3.2	0.0	—0.3	0.3	0.7	2.8
21–22	—2.8	—5.0	—4.3	—2.1	—2.0	—0.8	—0.6	—0.7	0.9	—0.3	—1.8	—1.8
22–23	1.5	2.2	6.0	4.0	3.1	1.4	0.6	—0.2	—2.5	—2.5	1.2	—1.3

TABLE XLIX. The Height, Standing.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	d	d/A						
15	131		63.80	±0.136	±1.96	2.65%			62.058	64.290	66.208	+ 0.490
16	395		65.93	±0.080	±1.56	2.36	2.13	3.34%	64.147	65.850	67.610	— 0.125
17	722		67.05	±0.059	±1.59	2.37	1.12	1.70	65.509	67.000	68.708	— 0.050
18	841		67.29	±0.057	±1.68	2.50	0.24	0.36	66.184	67.633	69.292	+ 0.343
19	750		67.90	±0.054	±1.50	2.21	0.61	0.91	66.547	67.651	69.514	— 0.249
20	645		68.55	±0.060	±1.50	2.18	0.65	0.95	66.753	68.252	69.865	— 0.298
21	493		68.60	±0.071	±1.58	2.30	0.05	0.073	66.743	68.215	69.831	— 0.385
22	328		68.45	±0.086	±1.56	2.27	—0.15	—0.215	66.894	68.352	70.280	— 0.098
23	232		68.62	±0.099	±1.51	2.20	0.17	0.248	66.940	68.522	69.980	— 0.098

TABLE L. The Weight.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus. Average.
				E	d	d/A							
15	131		107.0	±0.922	±10.60	10.0%	16.7%			95.9	108.5	118.5	+ 1.5
16	395		118.0	±0.531	±10.56	8.9	18.2	11.0	10.3%	106.2	116.9	127.8	— 1.1
17	722		125.0	±0.370	± 9.94	7.9	18.6	7.0	6.0	114.4	124.8	135.0	— 0.2
18	841		133.4	±0.400	±11.28	8.4	20.0	8.4	6.7	121.9	131.8	143.0	— 1.5
19	750		139.7	±0.360	± 9.86	7.0	20.5	6.3	5.0	127.1	137.0	147.5	— 2.7
20	695		141.2	±0.371	± 9.43	6.7	20.6	1.5	1.1	128.8	138.5	149.6	— 2.7
21	493		140.0	±0.456	±10.14	7.2	20.4	—1.2	—0.8	129.3	138.9	149.9	— 1.1
22	328		141.3	±0.500	± 9.07	6.4	20.6	—1.3	—1.0	130.1	138.7	150.6	— 2.6
23	232		144.0	±0.768	±11.81	8.2	21.0	2.7	2.0	128.9	138.3	149.1	— 5.7

TABLE LI. The Height, Sitting.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	*d*	*d/A*							
15	131		33.3	±0.088	±1.01	3.03%	42.7%						
16	395		34.5	±0.048	±0.96	2.80	52.3			32.481	33.500	34.282	—1.000
17	722		35.0	±0.032	±0.86	2.46	52.5	0.50	1.50%	33.271	34.180	35.030	—0.820
18	841		35.7	±0.027	±0.81	2.27	53.0	0.75	2.14	33.735	34.630	35.360	—1.120
19	750		36.5	±0.035	±0.98	2.70	53.7	0.75	2.10	34.098	35.055	35.749	—1.445
20	695		35.7	±0.027	±0.70	1.96	52.1	0.73	2.00	34.356	35.254	35.967	—0.516
21	493		36.0	±0.024	±0.54	1.50	52.4	—0.23	—0.62	34.772	35.445	36.064	—0.555
22	328		36.0	±0.040	±0.74	2.05	52.5	0.00	0.00	34.450	35.320	36.087	—0.680
23	232		36.0	±0.036	±0.57	1.58	52.4	0.00	0.00	34.593	35.333	36.123	—0.667

TABLE LII. The Perineal Height.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height. Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	*d*	*d/A*							
15	131		32.0	±0.131	±1.51	4.72%	50.1%			31.882	33.125	34.168	
16	395		33.2	±0.064	±1.29	3.89	53.5	1.20	3.80%	32.678	33.830	34.887	
17	722		34.0	±0.045	±1.25	3.67	50.7	0.80	2.41	33.534	34.600	35.761	
18	841		34.6	±0.040	±1.22	3.52	51.4	0.60	1.77	34.030	35.007	35.909	
19	750		35.9	±0.031	±0.86	2.40	52.8	1.30	3.76	34.338	35.243	36.102	
20	695		35.0	±0.038	±0.98	2.80	51.1	—0.90	2.50	34.431	35.310	36.256	
21	493		34.0	±0.076	±1.69	4.97	50.0	—1.00	—1.46	34.390	35.340	36.241	
22	328		35.0	±0.062	±1.14	3.26	51.1	1.00	2.77	34.574	35.492	36.500	
23	232		35.0	±0.073	±1.12	3.20	51.0	0.00	0.00	34.803	35.654	36.617	

TABLE LIII. The Circumference of Chest.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade,	Median Minus Average.
				E	*d*	*d/A*	*A/H*						
15	132		30.50	±0.123	±1.42	4.65%	47.8			28.385	29.952	31.363	—0.548
16	395		31.67	±0.066	±1.33	4.20	48.0	1.17	3.83%	29.707	31.101	32.356	—0.569
17	722		32.50	±0.044	±1.23	3.78	48.5	0.83	2.62	30.770	31.895	33.034	—0.605
18	841		33.46	±0.043	±1.26	3.50	49.7	0.94	2.00	31.577	32.685	34.034	—0.775
19	750		35.00	±0.038	±1.04	3.00	51.5	1.54	4.60	32.210	33.250	34.459	—1.756
20	695		34.30	±0.048	±1.22	3.55	50.3	—0.70	—2.00	32.426	33.588	34.724	—0.712
21	493		34.30	±0.052	±1.16	3.40	50.0	0.00	0.00	32.500	33.656	34.803	—0.644
22	328		34.35	±0.065	±1.18	3.43	51.8	0.05	0.02	32.642	33.776	34.891	—0.574
23	232		34.80	±0.079	±1.20	3.45	50.7	0.45	1.40	32.751	33.873	34.850	—0.927

TABLE LIV. The Lung Capacity.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average,
				E	*d*	*d/A*	*A/H*						
15	132		183	±2.303	±26.10	14.2%	40.9			152.4	178.2	202.2	—4.8
16	395		395	±1.091	±21.69	10.8	32.9	18.0	10.0%	176.5	193.5	217.8	—7.5
17	722		722	±0.820	±22.00	10.1	33.0	16.0	8.0	187.3	208.8	233.6	—8.2
18	841		841	±0.782	±22.87	10.1	34.0	9.0	4.1	197.9	219.0	240.8	—7.0
19	750		750	±0 642	±19.60	8.2	28.8	14.0	6.2	208.2	228.3	248.2	—11.7
20	675		675	±0.834	±21.19	8.8	30.8	—1.0	—0.4	211.3	233.2	255.3	—5.8
21	483		493	±0.940	±20.84	8.6	30.2	2.0	0.84	213.2	232.2	253.6	—8.8
22	328		328	±1.150	±20.83	8.5	30.4	5.0	2.08	218.5	237.9	259.2	—8.1
23	232		232	±1.250	±16.05	7.9	27.8	—4.0	—1.62	216.2	236.3	259.8	—5.7

TABLE LV. The Circumference of the Waist.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	*d*	*d/A*	*A/H*						
15	132		25.09	±0.095	±1.09	4.34%	3.93			23.79	25.12	26.23	+ 0.03
16	395		26.00	±0.052	±1.03	4.00	3.94	0.91	3.63%	24.76	25.77	27.01	− 0.23
17	722		27.36	±0.042	±1.13	4.13	4.08	1.36	5.28	25.35	26.45	27.69	− 0.91
18	841		27.90	±0.044	±1.30	4.66	4.14	0.54	2.00	25.98	27.22	28.40	− 0.68
19	750		28.60	±0.044	±1.21	4.23	4.21	0.30	1.08	26.31	27.60	28.76	− 1.00
20	695		28.62	±0.052	±1.33	4.64	4.17	0.02	0.07	26.51	27.98	29.20	− 0.64
21	493		28.68	±0.062	±1.38	4.81	4.18	0.06	0.21	26.38	27.67	29.23	− 0.99
22	328		28.80	±0.070	±1.28	4.48	4.21	0.12	0.41	26.50	27.81	29.17	− 0.99
23	232		29.20	±0.093	±1.42	4.86	4.25	0.40	1.40	26.71	27.89	29.47	− 1.31

TABLE LVI. The Span of Arms.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	*d*	*d/A*	*A/H*						
15	36		63.90	±0.130	±1.18	1.84%	100.0			62.89	64.50	66.51	+ 0.60
16	110		67.33	±0.091	±1.81	2.69	102.1	3.43	5.37	64.98	66.80	68.57	− 0.53
17	225		68.00	±0.064	±1.74	2.56	101.1	0.77	1.14	66.15	67.90	69.75	− 0.10
18	245		68.25	±0.060	±1.75	2.53	102.8	1.25	1.83	66.65	68.55	70.30	− 0.70
19	200		70.12	±0.062	±1.72	2.45	103.3	0.80	1.15	67.25	69.03	70.87	− 1.09
20	165		70.10	±0.072	±1.85	2.64	102.2	−0.02	−0.03	67.56	69.40	71.45	− 0.70
21	103		70.67	±0.076	±1.68	2.37	103.1	0.57	0.81	68.51	69.93	71.64	− 0.74
22	68		70.20	±0.108	±1.98	2.81	102.5	−0.47	−0.66	67.62	69.60	71.75	− 0.60
23	46		71.00	±0.093	±1.42	2.00	103.4	0.80	1.14	68.93	69.93	71.56	− 1.07

TABLE LVII. The Right Hand Squeeze.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	*d*	*d/A*	*A/H*						
15	36		61.0	±0.800	±9.12	15.0	95.4%			49.5	60.0	69.1	−1.0
16	110		71.5	±0.367	±7.30	10.2	108.0	10.50	17.20%	60.5	68.0	75.0	−3.5
17	225		77.5	±0.273	±7.33	9.0	115.6	5.97	8.30	68.0	75.2	82.6	−3.27
18	245		81.0	±0.245	±7.11	8.1	120.3	3.53	4.50	69.2	77.5	84.8	−3.5
19	200		85.0	±0.274	±7.52	8.8	125.2	4.00	5.00	74.2	82.0	89.8	−3.0
20	165		77.0	±0.316	±8.03	9.2	127.0	2.00	5.00	76.2	83.8	92.5	−3.2
21	103		88.0	±0.365	±8.11	9.2	128.3	1.00	2.30	77.6	85.8	94.7	−2.2
22	68		86.5	±0.449	±8.14	9.4	126.5	−1.50	−1.70	74.7	85.0	91.8	−1.5
23	46		86.6	±0.421	±6.42	7.6	126.2	0.10	0.10	81.2	89.0	96.5	+2.4

TABLE LVIII. The Left Hand Squeeze.

Age at nearest Birthday.	No. of Observations.	Unit of Measurement.	Average.	Probable Error of Average.	Probable Deviation.	Relation of Probable Deviation to Average.	Relation of Average to Height, Standing.	Absolute Ann'l Increase of Average.	Relative Ann'l Increase of Average.	25 Percentile Grade.	Median or 50 Percentile Grade.	75 Percentile Grade.	Median Minus Average.
				E	*d*	*d/A*	*A/H*						
15	36		60.0	±0.790	±9.06	15.1	94.0%			46.3	56.4	62.1	−3.6
16	110		70.0	±0.368	±7.31	10.4	106.2	10.0	16.6%	56.3	65.0	70.3	−5.0
17	225		76.6	±0.274	±7.43	9.7	114.3	6.6	9.1	66.6	73.5	81.0	−3.1
18	245		80.0	±0.250	±7.22	9.0	119.0	3.4	4.4	67.7	75.0	82.2	−5.0
19	200		83.0	±0.273	±7.43	9.0	122.2	3.0	3.8	72.6	81.5	87.8	−1.5
20	166		85.0	±0.322	±8.19	9.6	124.0	2.0	2.4	73.9	82.0	92.0	−3.0
21	103		97.4	±0.327	±7.26	8.3	127.4	2.4	2.8	77.2	84.5	91.8	−2.9
22	68		85.8	±0.463	±8.40	9.8	125.3	−1.6	−1.8	74.5	83.8	91.9	−2.0
23	46		84.7	±0.466	±7.10	8.3	123.3	−1.1	−1.3	78.8	85.0	90.9	+0.3

THE TRAINING SERVICE.

A FEW NOTES.

By Lieut. George R. Clark, U. S. Navy.*

The recent wise step made by Congress in giving to the Navy two thousand more enlisted men should call attention to the importance of having an adequate training service for our "man behind the gun." In 1879 England employed one-eleventh of her commissioned officers on training duty, while to-day we devote one officer in thirty-seven to that service. Again, England finds work for one-eighth of her warrant officers in that important field, while we give to it one in nineteen.

It has not required all of a two years' experience in the training service to show me that everything possible has been done with the limited means at hand; but when it is remembered that the only cruising vessels now available for this work are the Essex and the Alliance, it will be seen that the means at hand for keeping up our supply of 1500 boys are clearly inadequate.

Naturally, the first thought is to turn to Congress and ask for two or three vessels designed with a view to the special needs of the service; but that would take much time and not a little pleading, and meanwhile the men and boys are being enlisted.

If the Bering Sea trouble should straighten itself out enough to allow the Pacific Squadron to be reduced, I think it would relieve the situation to send around the Adams and the Marion (or Iroquois), fit them out with modern batteries like those of the Essex and the Alliance and add them to the squadron. They would then be in a condition to render effective aid on regular cruising duty when needed.

With this addition the number of boys carried by each of the smaller ships could be reduced from 108 to 90, thus giving more

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*U. S. Training Ship Essex.

room and adding to the comfort of all on board. As thus formed the squadron could readily train, in two cruises a year, all the boys from the Newport station, the average yearly enlistments there being about 720. If we could carry out this idea, and add the Lancaster as a gunnery ship, making short trips of a week's length from Newport, and serving as a "reservoir," so to speak, for the newly enlisted landsmen and boys returned from other vessels, we would have, at least, a step forward.

I would suggest that the four vessels be directed to cruise together in charge of the senior commanding officer, making a summer cruise to the Azores, Gibraltar, Madeira and Yorktown from July to November, and a winter cruise to the West Indies from January to May; November and May of each year being devoted wholly to target practice either at Yorktown or Gardiner's Bay, and December and June to be spent in port refitting.

The plan of visiting foreign ports excites the interest of the boys, increases their desire for further sea-going, and thus satisfies them with a service which they find has its compensations and rewards. In this, too, the commanding officer is furnished with a system of rewards and punishments in the granting or withholding of shore privileges, which can be used with good effect.

The practice in signals and the emulation and interest in drills and exercises generally that would result from squadron sailing could not fail to be of great benefit.

The key to success in training apprentices is to excite their interest. This once done, the rest is plain sailing.

A month of each cruise would not be too much to devote to exercises on shore and to target practice, for I think all will agree that, after all, the main thing in the training of men is to teach them "to fire at something and hit it." And, happily, this is something in which boys take a great interest and show gratifying progress after a very little instruction. A glance at the target report of the Navy for the quarter ending June 30th, 1894, will show that the Essex, with a crew of boys, stood No. 3 in a total of nine vessels. Among the first ten in a total of 258 firing, *seven* were Essex boys, each with a final merit of 100 or over. Among the first 64 were 40 boys from the same ship. This satisfactory showing was made at their first trial. If each draft of boys could be allowed at least two practices even better results could be obtained.

The subject of target practice may be considered the most important, with boats and signals following in the order named.

In regard to the methods of instruction and routine at sea and in port, a close observation of the methods employed convinces me that the principle of continuous instruction in one branch for a considerable length of time is the best. Those who "go down to the sea in training ships" know that it is difficult to make a boy think, and the next best thing is to employ what may be called the method of "reiteration"; that is, to keep at one subject until the boy gets it by absorption, so to speak. His thinking gear will gradually get in order as he grows older.

The truth of this is shown by our exercise at reefing topsails. This work is done six times a week without fail during the whole cruise, and even the dullest boys show a skill at the work that is encouraging.

Of this Commodore Bunce has said: "Training apprentices is best done by the repetition of facts until they are impressed on the memory, and in the repetition of acts until facility in doing them is acquired."

Speaking of this subject in a recent report to my commanding officer I said: "This principle of continuous instruction in one branch should be extended to the general routine at sea, where the time covering the whole cruise should be divided into five equal parts: the first devoted to sails, spars, compass and log; the second to marline-spike work and sail-making; the third to signals; the fourth to a review, and the fifth month to target practice. A half-hour each day to be given to gunnery."

This would carry out the principle as nearly as possible with a due regard to the number of subjects to be covered and the length of the cruise.

Again quoting from report: "The time spent on training ships should be regarded more as a preparatory and less as a finishing period. If, in the short time allowed, a boy be taught the importance of prompt obedience to orders, the general principles of discipline, the elementary branches of his calling and the confidence and skill gained in work aloft and general ship duties, all will be done that should be expected. The rest should be left to the actual work and the association with older men that come with service on board the cruisers."

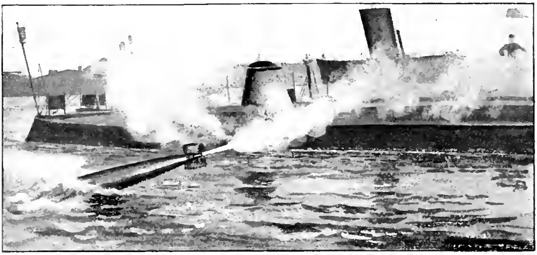
In this connection I suggest that so far as possible the boys be formed in one division on the cruisers, preferably at the secondary battery, in charge of a divisional officer and aid, who shall be responsible for their instruction and have general charge of them while on board. The instruction should be systematic and progressive.

An officer of one of the new cruisers recently remarked that the work of examining apprentices took a long time. When asked how many he had examined that day, he said "forty." On board the training ship it takes a week to examine that number.

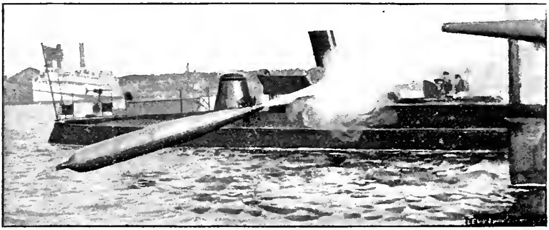
I know that I have laid down no elaborate plan, but if these few disconnected remarks attract any attention to this important subject they will have served their purpose.

In conclusion I cannot do better than to quote from Commodore Chadwick's report on the training system of France:

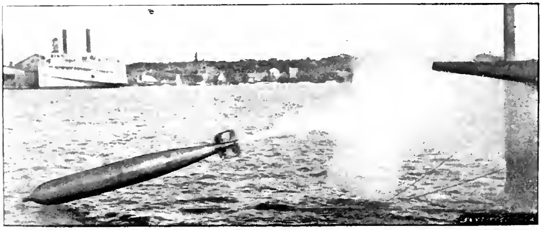
"The necessity of so training these men is clearly felt by the officers of the French navy in general; without this widespread feeling much of the instruction given in training schools, however perfect, must go for naught."



Photograph No. 1.



Photograph No. 2.—Torpedo No. 6—Run No.12.



Photograph No. 3.—Torpedo No. 6—Run No. 10.

THE PROBLEM OF TORPEDO DISCHARGE.

Compiled from the report of Lieutenant Frank F. Fletcher, U. S. Navy, commanding U. S. Torpedo-boat Cushing.

By Lieut. Albert Gleaves, U. S. Navy.

"Successful torpedo practice depends to the greatest extent upon successful discharge."—Lieut. Fletcher.

Previous to Lieutenant Fletcher's investigations of the subject comparatively little was known of torpedo ballistics. For the purpose of solving the problem of torpedo discharge Lieutenant Fletcher inaugurated and carried to a successful issue a series of experiments at Newport, R. I., which extended over several months, with the gratifying results of defining the relation between discharge and the final submerged angle of the torpedo, and establishing certain rules of fire that will not fail to rob the torpedo of its reputation for eccentricity, reduce to a minimum the errors of practice, and enable the gun-captain to handle the weapon with an intelligent idea of what may be expected of it under given conditions of discharge.

The official report gives a minute account of the experiments, which are remarkable alike for originality, simplicity and ingenuity. The details are admirably worked out, and where results do not blend, the discrepancies may be justly ascribed to the inaccuracies, not to say crudeness, of the recording instruments; they affect in no way the principles involved. The report itself, as a technical document, is exceedingly unique, using the word in its favorable sense.

By permission of the Bureau of Ordnance the substance of Lieutenant Fletcher's report to the President of the Torpedo Board is herewith given to the service. As nearly as may be consistent with the plan of this article the phraseology of the report is retained; for obvious reasons the methods employed and the instruments used in the experiments are touched upon lightly.

Generally speaking torpedoes are discharged from tubes that may be mounted either in broadside or in bow or stern, and in our service are installed above water. Broadside tubes are fitted with spoons, as shown in the partial midship section of the Cushing, Plate I; bow and stern tubes are fitted with the ball pivot. In this case the pivot tube takes the place of the spoon.

When discharged the torpedo is guided through the tube by means of a steel T stud located on top of the torpedo at its center of gravity. This stud travels in a slot extending the full length of the tube and spoon. The windage of the torpedo varies in different tubes and may be as small as a few hundredths or as great as 0.2 inch. Generally speaking, however, when the torpedo is in place it should take the grease all around the tube.

Before taking up Lieutenant Fletcher's report a close study should be made of the diagrams on Plate I, which graphically represent all the data relative to a normal run of a Whitehead torpedo; the essence of his report is contained in this chart, and it may be said that familiarity with these diagrams constitutes a fundamental requirement to a clear understanding of all that follows here.

With the mechanism in adjustment the most potent factor in the successful run of a torpedo is the initial dive, and this depends directly upon the angle at which the torpedo enters the water. This angle must be such that the resultant effect places the torpedo beneath the surface of the water pointing in the line of fire and at such an inclination that it will neither rise to the surface nor make a greater dive than 20 feet without coming under the influence of its own controlling mechanism. As the conditions that affect the angle of entry are not the same in all ships, it is of the highest importance to know how to vary each one so as to produce at all times a uniform *submerged* angle of entry, because it is this final angle that determines the depth to which the torpedo will make its initial dive.

There are five elements that influence the angle of entry; these may work together to produce a satisfactory result or they may be either partially or altogether opposed to each other. They are:

I. Impulse pressure (p).
II. Initial velocity (v).
III. Height of tube (h).
IV. Inclination of axis of tube (a).
V. Length of spoon (l).

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III. Height of tube (h).
IV. Inclination of axis of tube (a).
V. Length of spoon (l).

SHEET NO 1

RECORD OF A WHITEHEAD TORPEDO DISCHARGE

TORPEDO NO. 6 RUN NO. 15.

U S S CUSHING OCT. 29 1894.

F. F. Fletcher Lieutn. U.S.N. Comdg.

PRESSURE CURVE

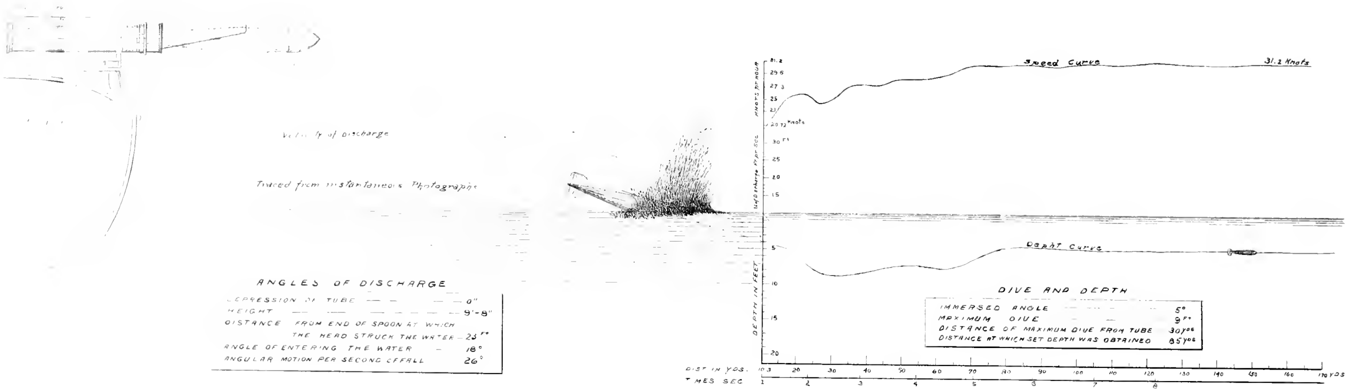
CHARGE ONE LAYER OF SPHERO HEXAGONAL IN THE BOTTOM AND FILLED TO THE TOP OF SPINDLE WITH SQUARE GRAIN	
PRESSURE DEVELOPED BEFORE THE TORPEDO MOVED	4 LBS
MAXIMUM PRESSURE	23 LBS
DISTANCE TORPEDO MOVED BEFORE MAXIMUM PRESSURE DEVELOPED	7"

VELOCITY OF DISCHARGE

TIME TO EXECUTE ORDER FIRE	31 sec
TIME TO IGNITE THE CHARGE AND TO MOVE THE TORPEDO	18 sec
VELOCITY IN BORE OF GUN	28 Ft pr Sec
VELOCITY IN AIR 1st 8 Ft	31.3 "
2nd 8 Ft	34.0 "
3d 8 Ft	34.0 "

SPEED CURVE

SPEED WHEN FULLY IMMERSED	19 Knots
ACCELERATION PER SECOND	5 Feet
FULL SPEED	31.2 Knots
TIME TO OBTAIN FULL SPEED FROM ENTERING THE WATER	4 seconds
DISTANCE AT WHICH FULL SPEED WAS ATTAINED	90 YARDS



ANGLES OF DISCHARGE

DEPRESSION OF TUBE	0"
HEIGHT	9'-8"
DISTANCE FROM END OF SPOON AT WHICH THE HEAD STRUCK THE WATER	23 Ft
ANGLE OF ENTERING THE WATER	18°
ANGULAR MOTION PER SECOND OF FALL	26°

DIVE AND DEPTH

IMMERSED ANGLE	5°
MAXIMUM DIVE	9 Ft
DISTANCE OF MAXIMUM DIVE FROM TUBE	30 yds
DISTANCE AT WHICH SET DEPTH WAS OBTAINED	85 yds

To Lieutenant Fletcher belongs the distinction of discovering the relation of these quantities to each other and to the angle of entry.

Before considering in detail the effect of the elements just enumerated it will be well to take in account what occurs in the tube when the powder charge is exploded. (See Plate I.)

As soon as a pressure of about 5 lbs. is developed in rear of the torpedo it begins to move and quickly attains a velocity of about 32 feet per second. When the guide stud leaves the T slot at the end of the spoon the C. G. begins to fall while the tail is still supported some distance inside the tube. During the time the torpedo is traveling the distance necessary to free the tail its motion is that of a pendulum, and the C. G. swings through a small arc with a constantly accelerating rate, due to gravity. The angular motion in the vertical plane thus imparted to the torpedo will continue at a uniform rate at the instant the tail begins to fall until the torpedo strikes the water. The value of this angular impulse depends directly upon the velocity of discharge, and a variation in the velocity gives a corresponding variation in the angle of entry of the torpedo for any given height of tube. Again, the angle of entry depends upon the time through which the angular impulse has acted, and is materially different whether discharged from a tube 4 feet or 10 feet above the water.

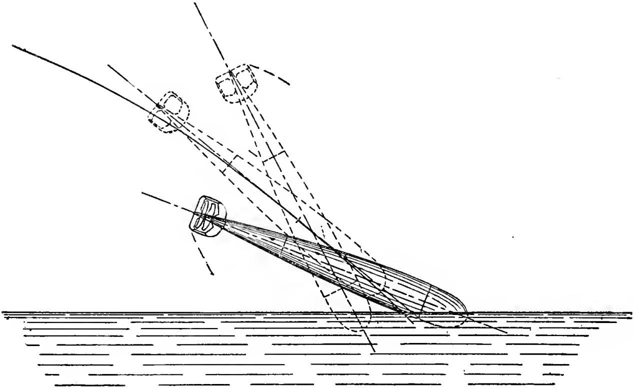
When the torpedo is free from the tube, its velocity of discharge remaining practically constant, a vertical velocity is also imparted to it by the accelerating force of gravity.

Thus, upon striking the water, the torpedo not only has an angular motion around its center of gravity, but a lateral velocity due to the impulse pressure and a vertical velocity due to gravity.

The resultant direction of motion is therefore at an angle to the surface of the water depending upon the two velocities, and the direction of its axis is also at an angle to the surface depending upon velocity of discharge, height and depression of tube.

The axis of the torpedo being inclined downwards, the head of the torpedo first strikes the water and is considerably retarded in the denser medium, while the after portion is free to fall through the air. The angular motion is thus not only checked, but a reverse angular motion takes place, tending to bring the torpedo back to horizontal. (See Fig.)

A combined electric speed and pressure indicator was especially designed by Lieutenant Fletcher for his experiments. The instrument worked satisfactorily and recorded with sufficient accuracy the data relating to pressure, velocity and speed.



The initial dive was obtained by a net, and in connection with this the depth register was used; thus the accuracy of the register was not only verified, but the dive before and after passing the net was obtained.

The angular movement of the torpedo was ascertained from a series of instantaneous photographs.

From the known position of the torpedo when entering the water, its known depth at the net, and also by means of the reading of the depth register, the final submerged angle was readily obtained.

A consideration of each element that affects the angle of entry and its influence upon that angle is now in order.

I.—Impulse Pressure and Velocity.

The charge of powder used for discharging the torpedo is about 4 ounces, one ounce of which is sphero-hexagonal pellets, laid in the bottom of the cartridge case, and the other 3 ounces are square grains such as are used in the 6-pdr. R. F. G.

The average maximum pressure in the tube was found to be about 21 lbs. per sq. in. and the velocity of discharge about 30 ft. secs. The torpedo moves when the pressure reaches about 5 lbs. per sq. in., and the maximum pressure is attained when the torpedo has moved about 4 inches. The maximum pressure is maintained for a distance of 10 inches and then gradually falls to 0. When the pressure disappears the tail of the torpedo is still 4½ feet inside the tube and the guide stud or C. G. 1½ feet from the end of the spoon. Before the pressure ceases the windage increases to 2 inches in the last 2¾ feet of travel.

The recording instrument was set to measure the velocity at every 8 feet. It recorded the instant the torpedo started and also the time required for it to move 1, 2, 3, 4 or 5 feet. It is clear, therefore, that the personal error of the gun-captain, or, what is the same thing, the time required to execute the order "Fire," was ascertained without difficulty. The data relative to velocity of discharge is tabulated on the chart; the increase of velocity after the first 5 feet is due to the accelerating force of gravity after the torpedo is free from the tube. The velocity of discharge was found to be 6.8 ft. secs. less than the average maximum velocity and about 4 feet less than the muzzle velocity. The average muzzle velocity was about 33 ft. secs.

Great stress has been laid by torpedoists upon the necessity of having a uniform velocity of discharge; but Lieutenant Fletcher is of the opinion that this has been unduly exaggerated. He found that pressures from 15 to 18 lbs. per sq. in. produce an average velocity of 29.8 ft. secs., while with pressures from 20 to 23 lbs. per sq. in. the averages were as follows:

Pressure.	Velocity.
20 lbs.	31.1 ft. secs.
21 "	32.6 "
22 "	32.6 "
23 "	35.2 "

A variation of 2 lbs. does not appear to influence the velocity of discharge except as shown by a number of averages, and Lieutenant Fletcher concludes that the importance of uniform impulse pressures, after making due allowance for inaccuracies of recording instrument, has been greatly exaggerated. He says:

"I have noticed that when several variable elements combine to induce a final result observers are apt to differ widely as to the cause of any variation in the results obtained. Thus when a torpedo broaches from its initial dive one observer attributes the fact to too small a height of tube above the water, another is quite sure it is due to escape of gas around the packing ring, while a third is equally positive that it is caused by grit beneath the reducing valve."

II.—Height of Tube above Water and Angle of Depression.

The pendulum-like action of the torpedo between the tube and water has been referred to, and from what has been said it is perfectly clear that the height of the tube has a very important bearing upon the angle at which the torpedo enters the water. The higher the tube, other things being equal, the longer will the torpedo be in reaching the water, and consequently the greater will be the angle that the axis of the torpedo will make with the surface of the water where it strikes. So also it will be admitted that a depression of the tube will increase this angle and by an amount equivalent to the angle of depression.

The experiments showed that with a height of tube between 5 and 6 feet the initial dive is about 9 feet, but from a tube 3 feet higher the dive is nearly doubled (17¼ ft.).

The influence of depression is more positive and regular, and it was deduced that a difference in the angle of depression of 6° has about the same effect upon the initial dive as an increase of 4 feet in height of tube above water. As a rule, then, *the initial dive is increased by the height of the tube above water and by the angle of depression.*

If this is not so the reason for the exception must be looked for in the variableness of the muzzle or horizontal velocity and the vertical velocity acquired by the torpedo when it leaves the tube, for it is these two velocities that determine the direction in which the torpedo is moving when it strikes the water.

The angular motion of the torpedo as it falls from the tube to the water has already been explained; it is evident that the rate at which it revolves around its C. G. is that which it had obtained at the instant the tail left the tube. Upon this angular motion depends the *entering angle* for the various conditions of discharge, and it is apparent that the value of this motion must depend upon the horizontal and vertical velocities mentioned above. Its value and the time of fall were accurately determined from instantaneous photographs. Its value was also determined theoretically. When the guide stud or C. G. of the torpedo leaves the end of the spoon and is free to fall, the tail is still 2.27 feet within the tube. The muzzle velocity recorded by the chronograph of 32 ft. secs. will give $\frac{2.27}{32}$ as the time of falling of C. G., during which the torpedo may be regarded as a compound pendulum. At the end of this time the C. G. has fallen .0766 ft. and has swung through an arc of fifty minutes; its velocity is therefore $\frac{32 \times 2.27}{32} = 2.27$ ft. secs. The angular velocity will be represented by an angle whose sine is 2.27 divided by the distance of the center of oscillation from the point of support on the tail, or 25° 30′ per second of fall. This is not mathematically correct, but it demonstrates the truth of the principles involved and agrees very closely with results obtained from the photographs.

From a knowledge of the law which determines the value of this angular motion of discharge we are thus enabled to ascertain how much the entering angle or initial dive is influenced by a variation in the muzzle velocity.

			Entering Angle.		
	Ang. Vel.	Ht. of Tube - -	5 ft.	7 ft.	10 ft.
M. V.	per sec.	Time of Fall - -	.56 sec.	.66 sec.	.79 sec.
26	31°.5		17° 38′	20° 48′	24° 48′
30	25°.83		14° 30′	17° 05′	20° 35′
34	21°.07		11° 48′	13° 54′	16° 40′

A variation of 8 feet in the velocity of discharge causes a variation of from 6° to 8° in the angle of entry of the torpedo according to the height of tube from which it is fired. The table also shows that the combined influence of 8 ft. variation in velocity and 5 ft. variation in height of tube can be made to cause a change in the angle of entry amounting to 13°. If the above influences are combined with that also obtained by 8° extreme depression of the tube the total influence exerted upon the angle of entry can be made to exceed 20°.

The service impulse charge gives a M. V. that varies from 30.5 to 34.5 ft. secs. A variation of 4 ft. secs. cause an increase in the angle of entry of $2\frac{3}{4}^\circ$ from a tube 5 ft. high and $3\frac{1}{2}^\circ$ from a tube 10 ft. high. These variations would probably not increase the initial dive more than four or five feet. From this it may be said in general that *a variation of 1 ft. in the velocity of discharge will cause a variation of about ¾° in the angle of the torpedo entering the water.*

The photographs that were taken not only afforded a means of tracing the actual position of the torpedo in air, but they also served as a means by which the velocities recorded by chronograph could be checked. The angular velocity was readily calculated by measuring the angle between the axis of the torpedo and the horizontal and the time of falling. With the angular velocity thus obtained and the known length of spoon the velocity of discharge was obtained. The velocity could be obtained also from the vertical and horizontal distance of the torpedo from the tube. The velocities obtained from the photographs agreed quite closely with those measured by the chronograph.

III.—LENGTH OF SPOON.

Upon the length of the spoon more than upon any other condition of discharge depends the angular motion of the torpedo around the C. G. and, consequently, its angle of entry. It can be shown that the sine of this angular velocity varies directly as the distance of the tail within the tube; thus *the shorter the spoon the greater is the angular velocity and entering angle.*

The length of spoon in use in the service is 5 feet. *For every inch this spoon is shortened it should make a difference of about* 1° *per second of fall.*

IV.—COMPARATIVE VALUE OF THE CONDITIONS v, h, a AND l.

What has been said refers only to the effect exerted by the above conditions individually upon the angle of entry. The effect of a change in one of the conditions can be offset by a proper variation of any other condition. That is, if a tube mounted 7 ft. above the water be lowered by the amount of 3 ft. 2 in. the angle of entry will be decreased by 4° 25′. This effect can be counteracted in any one of three ways: 1st, decrease length of spoon by 6 in.; 2d, increase the depression of the tube 4° 25′; 3d, decrease the velocity of discharge by 5.5 ft. secs.

V.—THE ANGLE OF ENTRY AND DIRECTION OF MOTION.

It has already been pointed out that when the torpedo first strikes the water the head is considerably retarded, while the after portion is free to fall through the air; that the influence of the various conditions which have been discussed determines the position of the axis of the torpedo at the instant of impact with the water; that the consequent retardation tends to reverse the angular motion, and that the resultant of these forces modifies the angle of entry and determines the *final submerged angle* upon which the initial dive directly depends.

This is illustrated in Plate II. The torpedo is plotted in three positions. In one position the axis of the torpedo is in the line of motion; in this case the angle of entry is unchanged and the initial dive is determined by the angle of entry only. The position in which the axis makes a less angle with the surface of the water than the angle of direction is the position ordinarily obtained in practice; it is caused by the resistance of the water acting upon the head of the torpedo as a fulcrum. The torpedo is shown in the other position where the axis makes a greater angle with the surface of the water than the angle of direction, and in this case the angle of entry would of course be increased and the torpedo would quickly reach a great depth.

RELATION OF ANGLE OF ENTRY TO INITIAL DIVE.

Angle of Entry.	Average Dive.
13° to 15°	9 ft.
15° to 17°	11¾ "
17° to 18°	15 "
20° to 22°	17⅓ "

VI.—DEFLECTION.

The horizontal deflections sometimes observed when the torpedo strikes the water may be due to vibrations of the tube and its mountings set up by discharge. The greater the height of the tube the greater the deflections.

TABLE No. I.

WHITEHEAD TORPEDO DISCHARGE.

COMPLETE RECORDS.

DATE.	No. of Torpedo.	No. of Run.	POWDER PRESSURES. lbs. per sq. inch.				VELOCITY OF DISCHARGE.							ANGLE OF DISCHARGE.				INITIAL DIVE.		
			Charge of Powder.	Pressure to start the Torpedo.	Maximum Pressure.	Maximum Pressure developed at	Personal Error to Fire.	Velocity Record commenced at	Time of first Record.	Velocity for 8 feet from first Record.	Velocity for 16 feet from first Record.	Maximum Velocity.	Average Velocity from igniting Primer to the Water.	Height of Tube.	Depression of Tube.	Angle of Entry.	Submerged Angle.	Passed through Net at	Shown by Register.	Maximum Depth.
							sec.		sec.	ft.	ft.	t.	ft.	ft.						
June 11,	1	17	3 oz. Sq. Gr. 1 oz. Sp. Hx.	6	18	3″.8	.2	18″	.19			29.3	22.1	6½	3°.5	21°.8		in deep water.		
" 26,	1	19	"	5	17	3″.1	.34	4″	.17	23.6	29.0	29.0	23.2	6½	4°	21°.6		struck bottom in 20 Feet.		
Oct. 9,	6	10	"	2	15		.31	8″	.18	28.0	29.7	33.4	26.3	6½	0°	15°.8	8°.2		15 ft.	19 ft.
" 19,	6	13	"	2	19	3″.8	.33	18″	.23	34.7	34.0	34.0	27.5	6¼	0°	13°.8	5°.5	10 ft.	10	11
" 29,	6	15	"	5	23	5″	.24	4″	.17	29.0	32.0	34.0	28.5	10	0°	16°.9	3°.0	7	8	9
" 30,	7	3	"	7	22	4″	.43	2″	.11				28.5	6½	0°	13°.2	2°.8	6	7	7
Nov. 1,	7	5	"		22		.28	2″	.16		30.3	34.0	29.4	7	0°	13°	3°.0	6	9	9
" 1,	7	6	"		21		.37	5 ft.	.29	27.6	30.3	34.5	29.0	10	0°	16°.3	5°.5		10	10
" 2,	7	7	"	5	22	3″	.36	5 ft.	.28	32.0	37.8	37.8	28.8	7	4°	17°.4	5°.5		10	12
" 2,	7	8	"	6	21	3″	.30	5 ft.	.31	33.3	34.5	35.2	29.0	6¾	4°	17°.0	3°.6	8	9	7
" 2,	7	9	"	6	22	3″		1″	.11	27.0	29.0	35.7	28.0	6¾	4°	17°.8	2°.5	6	7	5
" 3,	6	20	"	8	23	3″	.37	5 ft.	.31	40.9	42.0	43.0	33.4	8	6°	17°.4	8°.5	16	10	16
" 14,	7	14	"	6	22	4″	.47	5 ft.	.31	35.8	35.8	35.8	30.0	6½	0°	12°.3	8°.5	16	14	26
" 14,	7	15	"	5	20	5″	.37	5 ft.	.40	29.0	34.0	38.5	26.8	7¾	6°	22°.0	9°.9	18	18	18
" 15,	7	17	"	4	22	5″	.30	5 ft.	.30	29.1	32.8	35.3	28.5	7½	6°	20°.3	5°.5	10	14	14
" 15,	7	19	"	4	22	5″	.27	4 ft.	.27	31.4			29.0	10½	0°	17°	6°.5	12	8	27
" 15,	6	27	"	6	21	4″	.21	5 ft.	.33	26.6	31.4	36.0	27.8	10½	0°	17°.6	7°	13	10	13
							sec.	ft.	sec.	ft.	ft.	ft.	ft.	ft.				ft.	ft.	ft.
				5.2		3″.7	.33	2.7	.23	30.7	33.1	34.7	27.9	7½	2°.3			9½	10	14½

HONORABLE MENTION, 1895.

A SUMMARY OF THE SITUATION AND OUTLOOK IN EUROPE.

AN INTRODUCTION TO THE STUDY OF COMING WAR.

"Le temps de guerre est arrivé."

By RICHMOND PEARSON HOBSON, Asst. Naval Constructor, U. S. Navy.

Europe, from the beginning of its history, has been the world's great battlefield.

Few of its generations have passed without engaging in wars of the first magnitude; possession of its soil and predominance in its affairs have ever been contested by rival races and rival nations; but never, in all its belligerent history, has there been, as now, such an accumulation of the forces of war.

A bitterness now exists between the principal western nations that has but few parallels in all history, and never has invasion been so formidable as now, when the Slavonic wave of mountain-like proportion is sweeping westward. Never before has there been such promise of war.

The present generation has grown old, has expended its life in preparation. With the revolutions in the material of war and in the methods of expanding the personnel, time has been necessary for preparation. It has required long and laborious years to evolve the existing engines of war, to organize into armies and exercise under arms all the able-bodied men of entire nations, to perfect the weapons and means of defense, to improve the old and develop the new; but it may be said roughly that now preparation is complete (except with Russia, whose unlimited resources for war, checked only by want of wealth, may be considered as having no limit), for the entire nations *are* organized into armies, and the uses of the new agents have become more or less defined. Further preparation will be principally in increasing population and increasing wealth. Certainly improvements will continue as always, but they will be, in all probability, essentially improvements, not radical changes like those of recent years.

What may be termed the present order of things military and naval, which is such a vast advance over the old order of things so recently gone out, is now fully established, and will in all probability remain till the test of war.

On the whole, the nations of Europe are prepared, and though Russia is not prepared as she would like to be, to the extent that her population would permit, yet, as will be seen below, she finds an opportunity, a discord in the western family, which gives her an ally, produces an alliance which is not only prepared to accept, but also soon to offer war. There no longer exists the great retarding force of apprehension about the readiness for war. Further, the objects and policies of the nations have become established and clearly defined, except in the case of Italy, to be considered later, and the preliminary alliances have been formed. It only remains with diplomatic strategy to decide on the moment. No fact is so universally accepted abroad as the imminence, the very presence of war. It is a living actuality; not only every man in the armies and navies of the great powers expects to take part personally, but every individual with any hold on life expects to be a witness.

This imminent war bids fair to involve all of the six great nations of Europe, a population of about 324,000,000, of which about 74,000,000 are capable of bearing arms, possessing over 2,000,000 tons of war vessels afloat. In all this population there is burning a strong fire of patriotism, and efforts for putting forth entire strength will be aroused by all the great passions, ambition, hate, revenge, and fear of extermination. The war will be on a scale incomparably greater than any in the world's history.

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The issues will be of a twofold nature, in determining the historic rivalry of the western nations and the equally historic Russian march toward ascendency. The Franco-German struggle promises to culminate by irreparable disaster to the vanquished, as does also the French-English rivalry in African and Asiatic colonization.

The English and Russian rivalry in Asia will be decided forever in case of British defeat, and will be determined for many years to come in case of Russian defeat.

But there is a more far-reaching issue than that of the rivalry of nations. The Slavonic race, the last Aryan race that has arisen in Asia and Eastern Europe, is surging westward. This wave is relatively many fold more formidable than any of the Aryan waves of the past, all of which have ultimately succeeded in supplanting the waves that had gone before and in overthrowing a higher but less rugged civilization.

Recent foresight has led the Russian to cultivate the friendship of France, and has culminated in alliance.

Dissension among the western nations has been taken advantage of, and Russia proposes to drive her wedge home at the moment when France also attacks the other nations. The wedge would be driven home indeed by Franco-Russian victory, for France left alone would be powerless before the surging Russian wave.

So the issue involves not only the perpetuation or the overthrow of the vast British Empire and of the central continental powers, but also the heritage of European soil.

It will determine whether the western civilization, like the high civilizations of the past, has lost the ruggedness adapted to and necessary in this rugged world of ours.

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The study of this imminent war of such colossal proportions, which may alter radically the course of events of the world, is of greatest universal interest. But in addition, for those whose profession is the preparation and prosecution of war the interest is particular and vital, for then will come the first crucial test of the features of the new order of things, military and naval.

Smaller wars in distant lands may throw some light on the conditions of actual battle with modern material, but the conclusive lessons are to be learned only when vast masses of similar material are hurled against each other. In the shock of coming battle alone, when powerful weapons attack strong defense, will the anxious professional eye perceive the relative value and importance of the methods thus far adopted of disposing modern material of attack and defense; from the results of these engagements alone will the tactician be able to deduce the best methods of conducting modern material in battle. Thus, while the universal war will hold the partial fate of mankind at stake, it will at the same time solve the professional problems, insoluble in peace, that the new order of things has thrown out to those whose profession is war, and, above all, to those assigned to naval war.

To the United States before all will these lessons be of greatest importance, for if she has sufficient power afloat during the war to enforce respect for her rights as a neutral, she will become enriched by the expenditures of all the belligerent parties, will fall heir to vast shipping tonnage and world-wide commerce, and will be in a position to begin immediately on her ultimate national and naval policy.

The moment of relative weakness and impoverishment of the other nations will be a rare and vital one for the United States to forge to the front and initiate her natural strong foreign policy, and her naval strength being the means, her naval officers should be instantaneous in deriving the vital lessons for the new order of things to follow.

The coming war, which will give needed and necessary data for every branch of naval science, should thus be made the subject of special study by every officer of the United States Navy. From his own professional standpoint every officer should be prepared, should study the probable conditions, should see the needs and anticipate and, as far as possible, study beforehand the lessons to be learned in his own particular branch.

A necessary introduction to the intelligent study of any particular branch is a general knowledge of the whole subject of which the branch is a part, and he who expects to study a specialty in the coming war should first get a general and comprehensive idea of the war along its broad lines; he should have a general idea of international politics, should understand the sociological forces at work, the historic march and trend of the nations and races involved, should know the attitude of the powers toward each other, the actual alliances and antagonisms that are in existence at the present moment and those that the sociological forces are tending to produce; he should have an estimate of the relative forces, naval and military, present and prospective, of the two sides, with the existing alliances and with those toward which the forces are tending, and thence deduce the probable and possible course of events, the probable and possible times and characters of war, and the probable issue in each case.

Thus alone can he have the satisfaction that broad and comprehensive knowledge brings, thus alone will he be beyond surprise, prepared for any event; thus alone can he most intelligently and with best results pursue the preparatory study in his own specialty and be ready to learn the lessons of the war, to grasp instantaneously the solutions of the problems in his special branch and to have them ready for the immediate use of his country.

Thus every one who proposes to make a particular study of the coming war should first get a general idea of the situation and outlook in Europe, and a similar idea should be sought by all who take an interest in what is going on in the world, and who wish to look on with intelligence when the coming struggle comes.

A Summary of the Situation and Outlook in Europe.

I.

The development of the means of communication, freedom of speech, and the development of the press in recent years have widely disseminated among the masses of all the civilized nations a knowledge of what is going on in the world. As this knowledge increases, and as the masses realize more and more their power and possibilities, they assume a larger share in regulating the policies of government, foreign as well as domestic. The more the nation rules the greater is seen to become the importance of national interests in deciding questions of foreign policy. The great motor, self-interest, universal in nature, exalted in the masses, is translating itself directly into the councils of government. "Interests" are coming more and more to exclude sentiment, and are fast supplanting the ambition and caprices of rulers and dynasties. Though the forms of government have not greatly changed, the rulers have been coerced, in order to remain a force, into shaping their ambition to the lines of national interest and aspiration.

Where interest rules, power is the sole arbiter. In the councils of nations national power has become the coefficient of national importance, causing all the nations to tax heavily their resources for the increase of power. Along with the spread of knowledge among the masses there has been a growth of race feeling, consolidation, which has greatly extended the possibilities of the increase of national power. Indeed, national power, the strength of armies and fleets, has come to be measured by the population and wealth. The result has been that the small, poor nations are practically excluded from the councils, since poor nations cannot create and maintain great fleets, and small nations cannot have great armies, so that now the affairs of Europe are regulated by the six great nations alone.

The increase of strength, and its consequent advantages, due to concerted action, applies to the family of nations as to the household of a single nation, and consequently the nations tend to group themselves and combines are formed for mutual benefit.

Thus the advent of "interests" has caused the affairs of Europe to be regulated by only the few great nations, and has caused these few to divide into groups, while it has largely eliminated the uncertain elements depending on the personal traits of rulers, causing thus a great simplification in the study of international politics, with a promise of fruitfulness hitherto impossible.

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In the grouping of nations, coincidence or similarity of interests is the great natural regulator, tending toward becoming exclusive as "interests" tend more and more to dominate.

National interests are: (1) commercial advantage; (2) ambition for extension of sway, for expansion of territory and colonies; (3) sentimental interests, chiefly passions, the chief among which is hatred, race and national hatred (with Russians there is an additional religious sentiment or fanaticism); (4) self-defense. Ambition and passion are integrals or summations of the aspirations and animosities of the nation down its historic march.

In general terms, all of the nations have more or less conflicting aspirations in African colonization, particularly Great Britain, Germany, and France.

For commercial advantages, all the nations would tend to combine against Great Britain, the monopolist. But commercial advantage, though steadily growing in importance, has not been and still is not the dominant factor, at least in the grave questions of war and peace. Ambition and self-defense against ambition control where national life is at stake, as it will be in the coming war.

Two nations of the six are ambitious, the other four are not. Great Britain, Germany, Austria-Hungary, and Italy are contented with the present boundaries in Europe. France and Russia are discontented and wish to change them. Ambition and lack of ambition thus divide them into two groups. Self-defense against ambition gives the same grouping, with the exception that Italy, who has no fear of immediate aggression (though she should have for ultimate aggression), would, from her geographical position, become a spectator.

In general terms, the nations without ambition have had their passions as well as their ambitions satisfied in modern history, and wish to perpetuate peace to afford opportunity for internal development, to allow free competition for the markets of distant lands, to have amicable understanding about the colonization of unoccupied countries, while the two ambitious nations have had their ambitions thwarted or find them still unsatisfied, and have had their passions fanned by recent defeat. Thus the discontented and ambitious nations are essentially aggressive, while the contented nations without ambition are essentially passive.

Russia, with her great ambition for expansion, is checked in southeastern Europe and in Asia by Great Britain. French ambition in North Africa and in Asia is likewise checked by Great Britain, while all down history British expansion has steadily been largely at the expense of French colonies, and the French race, peculiarly susceptible to passion, has inherited toward Great Britain an accumulated hatred, profound, uncompromising, radical, that has no parallel except in Rome and Carthage.

The Russian frontier presses hard on Germany and Austria-Hungary. The German frontier presses hard against France, whose ambition has been trodden on. Toward the German, and in particular toward the Prussian, the Frenchman has a bitter, inherited hatred, fanned to white heat by shame at recent defeat. Thus Russia, with insatiable ambition, and France with ambition and passion, are in complete accord and form a natural alliance for aggression against Great Britain and Germany, who would be naturally allied in defense.

Peril from Russia causes Austria-Hungary to seek alliance with Germany, though this alliance involves France as an enemy, from whom there is ordinarily no fear of aggression, while France willingly accepts Austria-Hungary as an enemy while it secures a stronger alliance with Russia.

The natural alliances for Europe would thus be Russia and France for aggression, Great Britain, Germany and Austria-Hungary for self-defense against aggression.

Italy's ambition and passion have been satisfied in modern history, though she has naturally desires for Austrian territory and territory in Northern Africa, and, it may be, for some French territory also; yet on the whole she is contented while the process of unification is working within. Her geographical position and freedom from real danger of immediate aggression combine to mark her a spectator.

Thus Europe, in its natural condition, would present the six nations, five in two alliances, the sixth a spectator. This would be the aspect for subserving *immediate* interests, and toward it all the forces are at present tending.

If, however, *ultimate* interests were consulted the scene would change. Five nations would flow together and enlist all their weaker neighbors, to offer one undivided front of self-defense against Russia, whose ambition, read from facts and in history, does not stop short of two continents.

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But causes have countervened the natural grouping, not only in view of ultimate interest, still but vaguely foreshadowed, but also in view of immediate interests. It is only very recently that "interests" have come to be dominant. Great Britain is not allied with Germany and Austria-Hungary, and Italy does not hold the position of a spectator.

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Austria-Hungary and Germany, early realizing a common danger from Russia, formed in 1879 a secret alliance of defense. When France had rallied from defeat, the extraordinary measures for increasing her national strength were taken in Italy to be a menace, and upon the French occupation of Tunis, frightened at the representation that France had unfriendly designs, Italy joined Germany and Austria-Hungary in the Triple Alliance of defense, with the object of maintaining peace in Europe. This alliance was proposed in 1881 and adopted in 1882, signed in 1887 and renewed for six years in 1891.

France and Russia have only recently fully recognized their remarkable community of interests in Asia and in Africa, as well as in Europe. Only as recently as the Crimean War, France through sentiment joined a natural enemy against Russia, her natural ally, but Cronstadt and Toulon mark their coming together in the strong bonds of common interests. The Dual Alliance, a stable and natural one, is now a universally recognized fact in European politics.

Great Britain is pre-eminently the power whose foreign policy has been steadily directed by national interests, without a tinge of sentiment. Looking over the earth, she early perceived the rich fields beyond Europe, and set her ambition on colonial expansion, with an eye to the commercial advantages that colonies offer the mother-country. A steady, unswerving colonial policy, command of the sea and race aptitude have so far furthered commercial enterprise that she has outstripped all the other nations in the race for foreign markets, and, owning the bulk of the world's shipping, stands without a rival the great commercial monopolist. Having kept a naval force sufficient to overwhelm the force of any probable enemy, and knowing that her islands are free from invasion as long as she controls the sea, she has naturally, being sufficient unto herself, adopted a policy of isolation with respect to continental politics, except where her colonies and commerce are concerned, and has been able to spare herself the heavy burden of standing armies that weighs down the continental powers, devoting her energies and her vast wealth exclusively to the maintenance of her power by sea. Thus isolation has been her natural policy, notwithstanding her community of interest for defense with the central continental powers, even where she considered the possibility of an alliance against her. Even now, facing the formidable Dual Alliance, she sees her power superior to theirs combined. However, on account of differences and coincidences in the shipbuilding programmes of the three countries, an inevitable moment is fast approaching when the strength of the allied enemies will be greater than her own, when she cannot longer lay reasonable claim to the control of the sea. Her enemies being aggressive, this moment will be one of supreme danger. Isolation then, as far as reason can be applied to probabilities, would be fatal; its voluntary continuation would be rash madness; its advantages, hitherto unaccompanied by danger, will be subordinated to self-defense, which will then be paramount to all other interests. Moreover, this moment of weakness will coincide with the time for the renewal of the Triple Alliance. Italy's interests are setting heavily against such renewal, and a powerful motive against her continued adherence will be the danger of sharing in defeat. If Great Britain joined, this danger would be removed. She would find refuge, and, at the same time, would save Italy, who, after withdrawing, would not improbably go over to the other side. As the day approaches, forces will set stronger and stronger toward her joining, but as yet the indications are slight, and Europe now presents the spectacle of the Dual Alliance of France and Russia drawn up for aggression before two distinct enemies, Great Britain and the Triple Alliance of Germany, Austria-Hungary and Italy.

II.

What should be looked for from such a situation in Europe? When should war be expected? From what quarter will it probably come, and what will be its probable course? The aggressor of course is studying all the possible plans of attack. He will naturally choose, having the choice, the time, method and circumstances most advantageous to himself. The key to the future thus lies with the Dual Alliance, in the study of the best plans for it to adopt.

The best way to attack two enemies is to attack them in turn. The best way to begin an attack on a compound enemy is to disintegrate him. Can the Dual Alliance attack either enemy without the participation of the other? Can the Triple Alliance be disintegrated? The probable events to come are contained in the answers.

Russia is casting glances over the territory south of her frontier along its whole extent. She longingly covets that portion shutting her off from the Mediterranean, and long since would have possessed it had not the western powers interfered. Frightened at the thought, they have steadily opposed, in council and in war, the conquest of Turkey. If now Russia, with France come over to her side, were victorious in continental war, no sea power, no power under the sun, could prevent the immediate conquest of Turkey; and France, with the same object of striking a blow at the English occupation of India and Egypt, would aid Russia in an invasion of Asia Minor, Persia and Syria. Nothing could prevent the Russian frontier from pushing southward over Roumania, Servia and Bulgaria, over Turkey in Europe and Greece, from crossing into Asia Minor to girdle the Black Sea and sweep down through Syria to circle the eastern shores of the Mediterranean, from pushing down from the Caucasus to spread around the base of the Caspian Sea and reinforce the wedge pointing and already entered toward India. Egypt would fall from the hands of the English and India would follow at a not distant day. With the central powers defeated, all the prodigies of English valor would be powerless to prevent this Franco-Russian conquest. Great Britain, therefore, would never remain a spectator to Franco-Russian victory on the Continent. Consequently, in attempting to defeat the Triple Alliance first, the Dual Alliance would have to engage Great Britain also. To attack the continental enemy would be to attack both enemies.

But if the insular enemy were first attacked, would the continental enemy enter? It would be suicidal indeed in the Triple Alliance to remain spectator and see the Dual Alliance come into control of the sea. Italy, with her long coast lines, would withdraw post-haste and put in a plea to the enemy; but even if she remained, the power of the enemy, already preponderant, would soon become irresistible. The defeat of Great Britain would thus be fraught with the greatest dangers, yet the probability is that the Triple Alliance would remain spectator, for the treaty compact is essentially one for defense only. If, during the conflict between the Dual Alliance and Great Britain, the tide began to set in favor of the former, Italy certainly would not consent to go to war; self-defense *should* cause Germany and Austria-Hungary to enter without her, but the indications point to their remaining aloof. The Triple Alliance acknowledges no obligations to Great Britain, and there are even elements blind enough to relish being spectators to the defeat of the power which rivals and interferes in their colonization and commercial enterprises, and which has steadily considered itself self-sufficient enough to decline all overtures from the Alliance. Further, the Czar (now the late Czar) is undertaking to draw closer the frontier powers, particularly Germany, the directing head of the Alliance, by commercial concessions, to increase the commercial relations between them and Russia, which, when vast and important, form the best of guarantees against a rupture of peaceful relations; and these overtures are being favorably received and reciprocated, notwithstanding the fact that their unquestionable motive is to draw bonds around the continental enemy to hold him fast while the insular enemy is being disposed of. The probabilities thus point to the non-interference of the Triple Alliance.

Furthermore, there are decided advantages for the postponement of the conquest of the Continent. There are growing elements of disintegration and of internal disaffection at work in their enemies, and an entire accord and unity of purpose within themselves, and it would be surer to engage Great Britain before Italy withdraws, for this withdrawal would open the eyes of the English, and it is not improbable that Great Britain would thereupon join panic-stricken Germany and Austria-Hungary in a new consolidated Triple Alliance, which would offer a formidable front of resistance to attempted aggression.

After the overthrow of Great Britain and the disintegration of the Triple Alliance by the withdrawal of Italy that would follow, the conquest of Germany and Austria-Hungary by the armies whose strength would remain unimpaired by the sea struggle, would be an easy task, whether Italy joined in the conquest or remained neutral, or even if, as is against all probability, she renewed the Triple Alliance.

Egypt and India would then fall like ripened fruit, almost without struggle, and Europe, Asia and Africa would be at the feet of the conquerors.

Thus the best plan for the Dual Alliance to accomplish its schemes of universal conquest is, to first overthrow the British power by sea, then to conquer the central continental powers.

The invasion of the British Isles from the Continent is impossible while the British fleet controls the approaches. It was impossible for the great Napoleon himself, who found in this fact his bitterest experiences. The presence of the central powers, all equipped on the frontiers of France and Russia, would prevent the dispatch of troops against Egypt and India. The struggle, consequently, will be essentially by sea, while the integrity of the armies destined for the continental powers will remain intact.

When will the issue probably take place? At the time most advantageous for the aggressor.

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In the days of sail power and wooden hulls, before the differentiation of types, when all vessels were on an equal footing for defense, and, when sizes were not too disproportionate, for offense also, naval strength was fairly estimated by aggregate tonnage, or even by numbers of vessels, admitting, as is always necessary in investigations on this subject, that unknown elements of personnel are equal. At the present day, however, the protection and destruction of defenseless shipping and commerce is assigned to vessels whose powers of combat are small. Consequently, a large portion of the tonnage and a still larger proportion of the numbers of vessels, particularly for the commercial powers, cannot enter the combats that will decide the issue of struggle by sea. Being outside of the sphere for which they are built, with inadequate protection and inferior powers of offense, they would, if they entered, meet wasteful destruction, without inflicting appreciable injury. It can be assumed that unarmored tonnage will not appear in decisive combat except in an auxiliary rôle.

The life of vessels built of metal is long, being about one and a half times as long again as the average life of man, and the development in naval construction is rapid, being without a parallel in the encyclopedia of progress. Navy lists are consequently swelled with the names of vessels in a good state of preservation, now obsolete, of inferior value, which cannot enter a rational estimate on an equal footing with vessels of recent date.

In broad lines, sufficient for the present purpose, the armored tonnage, on which the issue of naval engagements will depend, can be classified as standard armored tonnage and armored tonnage of inferior quality. Inferior tonnage will avoid engaging standard tonnage for the same reasons that unarmored tonnage will avoid engaging armored tonnage. Consequently, the first series of engagements, those on which the nations' hopes will be centered, will be between fleets of standard tonnage. The standard tonnage that survives will be of enhanced value, if repairs are sufficiently prompt to enable it to enter the subsequent engagements between inferior tonnage. Inferior tonnage has its greatest value where standard tonnage is equally matched with the probability of mutual destruction.

Armored cruisers, a type of recent, wide development, are included in the estimates of inferior armored tonnage, for, though destined in the first instance to engage inferior cruising tonnage, they could figure well in the subsequent fleet engagements between inferior armored tonnage, and, with the choice of time, of position, and of method of attack insured by superior speed, could, in certain instances, find advantageous employment in the destruction of inferior battle-ship tonnage.

Coast defense vessels of recent date are entered in the class of standard tonnage, as the probabilities are that the engagements will take place within their radius of action.

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The relative naval strength of Great Britain is advancing by oscillations. The present moment finds it at the upper limit of a swing, caused by the completion of the programme of the great Naval Defense Act of 1889. It will begin an immediate descent on account of the failure to lay down new vessels during the execution of this programme. The descent will be sharp and sure, the lowest point being reached in 1896 and early in 1897, before which date, practically no addition will be made to armored tonnage, the bulwark of naval strength. On the other hand, the naval strength of both France and Russia is on a rising curve, whose rise is steady, rapid, sure, and presents no point of inflection.

At the present moment* the British naval force musters 261,690 *standard armored tons;* the Dual Alliance musters 215,952 tons, 144,470 French and 71,482 Russian. The British estimate includes the Royal Oak, Revenge, Repulse, and Barfleur, of the Naval Defense Act. The French estimate includes the Brennus and the Jemmapes. The Russian estimate includes the Navarin and Gangut. The line for standard tonnage is drawn in the British estimate at the Colossus and Edinburgh, launched in 1882, the Conqueror and Hero, of date of 1881; in the French estimate, at the Caïman class, the earliest of which, the Terrible, was launched in 1881; while all the vessels in the Russian estimate are subsequent to 1886.

In *inferior armored tonnage* the British force is now 350,590 tons, while the force of the Dual Alliance is 245,812 tons, 155,186

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* The following estimates were made in the summer of 1894.

French and 90,626 Russian. The British estimate includes 52,930 tons of coast defense vessels. 253,730 tons, including all the coast defense vessels except the Rupert, carry muzzle-loading guns. Of the total, 56,000 tons are armored cruisers, the Aurora class, the Impérieuse and the Warspite. The French estimate includes 43,146 tons, and the Russian estimate 36,836 tons of coast defense vessels, a total of 79,982 tons. This coast defense tonnage includes modern armored gunboats, 8 French of 11,327 tons total, and 2 Russian of 2984 tons total. All the guns carried are breech-loaders; but, on the other hand, 75,615 tons of the French contingent have wooden hulls, placing them somewhat at a disadvantage of defense on account of shattering and splinters and fire. Of the total, 19,900 tons are armored cruisers, 6200 French (the Dupuy de Lôme) and 13,700 Russian.

The coast defense vessels included in this estimate are mostly of old date, having a very small radius of action. The probability is that the engagements between the fleets of inferior tonnage will take place beyond this radius of action. The comparison of forces will consequently be more accurate by the elimination of coast defense vessels from both sides. The British inferior armored tonnage, without coast defense vessels, is 297,660; that of the Dual Alliance is 165,830, 112,040 French and 53,790 Russian.

The mean date of launch of the British standard armored tonnage is 1888, while that of the Dual Alliance is 1886, that for France being 1885 and that for Russia 1889. The average British standard ton is two and a half years (two years and four months) more recent than the average ton of the Dual Alliance. This lapse in an epoch where development and improvement have been so rapid guarantees a marked superiority in *quality*.

The mean average date of launch of British inferior armored tonnage is 1873, while that of the Dual Alliance is 1876, that of France being 1877 and that of Russia 1874. The average inferior armored ton of the Dual Alliance is three years more recent than the average ton of Great Britain (the dates do not change whether coast defense vessels enter or are eliminated). Progress was less rapid at this epoch. Three years insure a superiority of quality, but not so marked as the same lapse would insure at a more recent date.

All the armored cruisers are of recent date and of high speed and great coal endurance, and, having great resulting strategic superiority, would be at a marked premium over the average inferior battle-ship for the subsequent engagements. Here, in armored cruiser tonnage, Great Britain preponderates by 36,100 tons.

Thus, at the present moment, Great Britain has for the first series of engagements with the Dual Alliance a superiority of 45,738 standard armored tons, the average ton being of a superiority of *quality* guaranteed by two and a half years of rapid progress. For the subsequent series of engagements she has a gross superiority of 104,778 inferior armored tons. Eliminating coast defense tonnage, she has a superiority of 131,830 tons, though the *quality* of the average ton is inferior by three years of progress at the epoch of twenty years ago, though this inferiority, due to later date of average launch, is offset by a superiority due to an excess of 36,100 tons of British armored cruisers.

Thus at the present moment British force by sea preponderates over that of the Dual Alliance for the first series of decisive engagements in the proportion of 1.21 to 1, and is of marked superiority of *quality*, while for the subsequent series of engagements the proportion is 1.79 to 1 (coast defense tonnage being eliminated).

It would be folly for Russia and France to precipitate the conflict now. Immediate war need not be expected.

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What are the prospects for the future? Will the Dual Alliance find a more advantageous moment when its force will equal or preponderate over that of its enemy? What will be the additions to the strength of both parties? What will be their relative strength when British force passes down from its present maximum to its coming minimum in 1896-97?

The first battle-ships to be added to the British fleets are the Renown, Magnificent, and Majestic. The first of these to be added, the Renown, would go in commission early in 1896, in the ordinary course of events; the other two would come later. Supposing that construction is hastened, and that the Renown can be added by the autumn of 1896, the addition would be 12,350 standard armored tons. The Magnificent and Majestic cannot be hoped for before late in 1897. In the meantime, France will add the Tréhouart, Bouvines and Valmy, the Jauréguiberry, Charles Martel, and Lazare-Carnot, and, by accelerating construction, the Masséna, and, possibly, the Bouvet, an addition of 78,356 standard armored tons; and Russia will add the George the Victorious, the Three Saints, and, by accelerating construction, the Sevastopol, Petropolovsk, Poltava, Admiral Senyavin, Admiral Ushakoff, and the Cisoi-Velikie, an addition of 72,802 standard armored tons, making a total addition for the Dual Alliance of 151,158 tons. The strength of the two parties in standard armored tonnage will then be: Great Britain 274,040, the Dual Alliance 367,110; 222,826 French and 144,284 Russian.

In *inferior armored tonnage* Great Britain will make no additions. Russia will add the armored gunboat Otvajuy, of 1492 tons, and France will add the four armored cruisers of the Charner class, 18,696 tons, of most efficient quality.

Admitting that the Renown will be launched in 1895, and that the average date for the vessels to be added to the force of the Dual Alliance will be 1894, the mean launching date of British standard armored tonnage in 1896 will still be 1888, while that of the Dual Alliance will become 1889, that of France being 1888 and that of Russia 1891. The mean date of launch of British inferior armored tonnage will remain 1873, while that for the Dual Alliance will become 1878. Thus, toward the close of 1896 and early in 1897 the Dual Alliance will have for the first series of engagements with Great Britain a superiority of 93,070 standard armored tons, while its average ton will be of more recent date (about ten months) than the average British ton. The British inferior armored tonnage will still be superior by 111,642 tons (coast defense vessels being eliminated as before), though its average date of launch will be four years and two months earlier than that of the Dual Alliance, and its value will depreciate from the fact that the probability points to the survival of a considerable force of the standard armored tonnage of the enemy after the first engagements.

Thus, though the British force now preponderates over the force of the Dual Alliance for the first series of decisive engagements in the proportion of 1.21 to 1, it will witness in 1896-7 a preponderance of the enemy in the proportion of 1.34 to 1. At present the British inferior armored tonnage would find the seas clear of hostile standard armored tonnage after the first series of engagements, and could throw in to advantage in the subsequent series of engagements its heavy preponderance in the proportion of 1.79 to 1; but in 1896-7 the first engagements would leave hostile standard armored tonnage to impede and overcome the British inferior tonnage preponderating in the proportion of 1.6 to 1. The average British standard ton, which is now two years and four months more recent than the average standard ton of the Dual Alliance, will in 1896-7 be ten months older. The average British inferior ton, which is now three years and one month older, will in 1896-7 be four years and two months older.

Thus both preponderance in quantity and superiority of quality, which now belong to the British fleets, will pass over by 1896-7 to the fleets of the Dual Alliance.

This situation will be inevitable. No armored tonnage resulting from the scare and crusade of last fall and winter can enter in line before late in 1897, no matter how great the urgency, and the Majestic and Magnificent, as mentioned above, a total of 29,800 tons, will come too late for the moment of relative weakness. Great Britain will inevitably see a preponderance against her of 93,070 standard tons, more than one-third of her entire standard armored tonnage.

Every indication points to her enemy's seizing this unhappy moment to make the attack. It should be made, as stated above, before the expiration of the treaty compact of the Triple Alliance in 1897, in order to insure Great Britain's being left alone. There is no doubt that France and Russia both appreciate the situation. The extraordinary activity in the shipyards of both countries has undoubtedly one common concerted object, to enable the Alliance to seize the rare opportunity which both powers have vainly longed for, but which no nation has yet had since Nelson bequeathed to Great Britain the control of the sea.

The non-interference of the Triple Alliance being guaranteed, the odds will be heavily in favor of the Dual Alliance, notwithstanding the traditional valor and skill of British officers and seamen, and notwithstanding the preponderance still of British inferior armored tonnage, for defeat in decisive engagements of the first series, between standard armored tonnage, with hostile standard tonnage still surviving, can never be redeemed afterwards by inferior tonnage.

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After the defeat of Great Britain, the next step in the plans of the Dual Alliance will be the conquest of the central powers. The first step toward this conquest will be the disintegration of the Triple Alliance. To effect this, Italy's burden under the alliance is being made as heavy as possible by French financial policy. Italy will be threatened against remaining, will be allured to withdraw, and tempted to cast her lot in with the Dual Alliance. There can be little doubt, as will be seen further, that she will decline to renew the treaty alliance on its expiration in 1897, were Europe to remain as it is. If, in addition, the fall of the British Empire precedes, the imminent danger from the threatening victor would do away with any hesitation. She would certainly withdraw to isolation. France and Russia would then make overtures for her joining them, requiring a light burden, guaranteeing certain victory, and offering rich rewards in the division of spoils, which would be the more acceptable that they would be largely at the expense of her old enemy.

Italy having withdrawn, the struggle with Germany and Austria-Hungary would be essentially on land. If Italy remained neutral, France and Russia would offer for invasion, at the present moment, 1,416,000 men on the peace footing and 6,630,000 on the war footing, against an opposing force of 856,400 men on the peace footing and 4,380,000 men on the war footing. This heavy superiority will be greater in 1897, for the aggressors have a population of 165,000,000 in entire accord to draw from, while Germany and Austria-Hungary have but 91,000,000, with dangerous elements of discord growing day by day. There would be no need of delaying for further weakening of the enemy, for the working of socialistic disaffection in Germany, and the race dissensions in Austria-Hungary, and the serious seeds of disloyalty sown by Slavic influence in the eastern divisions of the Austro-Hungarian army. The Dual Alliance could march to the conquest with entire assurance on the morrow of British defeat.

If Italy joined in the conquest, the unhappy powers would be invaded from the south as well as from the east and west by an additional force, numbering about 259,000 men on the peace footing and about 2,000,000 men on the war footing.

Should Italy, against all her interests, against all probability, remain with the Triple Alliance, the conquest would involve a fierce struggle by sea as well as by land. The fleets of the Dual

Alliance would return shattered from the destruction of the British fleets. Time would have to elapse before they could be sufficiently reinforced. It would not require long, however, for the armies of the Triple Alliance are coming to absorb all the resources. The navies for new construction receive less than one-third of what the Dual Alliance now appropriates, and the disproportion will become greater and greater as Italy is ground down lower and lower under her financial burden, and as the elements of disaffection work in the German nation. The armies are now nearly balanced, with a slight preponderance on the side of the Dual Alliance. The preponderance, for the reasons already mentioned, will grow steadily larger each year. The inevitable conquest of all three central powers would follow not many years later. Nothing could save the Continent after the overthrow of British power by sea.

The next step in the plans of the Dual Alliance, the conquests beyond Europe, would be practically achieved. No serious opposition could be made. They could be taken possession of at leisure. The day France and Russia, after British overthrow, look up from the battlefields of Austro-German defeat, they will see their frontiers start on the march across southeastern Europe, into Africa, into Asia. There will be no serious obstacle in the way of this march toward the circumference of three continents, not even the walls of China or the deserts of Africa. The conquering powers would control the Eastern hemisphere.

Such are the best plans for realizing the highest possibilities opened up to France and Russia by their alliance, and the probability is that such, in the main, are the plans they have concertedly adopted. An unforeseen event might, however, precipitate a conflict between the Dual and the Triple Alliance against the wishes of the former. If it came at the present moment, the Dual Alliance on land would throw for the first wave 1,416,000 men against 1,115,000, and a total of 6,630,000 men against 6,380,000 men. On sea, it would send 215,952 standard armored tons to engage 218,749 standard armored tons, equal fleets, which would mutually destroy each other and clear the seas of standard tonnage. Then it would send 245,812 inferior armored tons to engulf 120,722 tons. Each year of postponement, for the reasons mentioned above, will mark a heavier and heavier preponderance for the Dual Alliance. For instance, in 1896, on the sea, the standard armored tonnage, at present about equal, will stand 367,110 tons for the Dual Alliance and 235,791 for the Triple Alliance, the inferior armored tonnage being 266,000 and 131,382 respectively.

The probability would thus point more and more strongly to Franco-Russian victory; but when the tide began to set this way, Great Britain, for the reasons stated above, would enter. Throwing into the struggle, at the present moment, 261,690 standard armored tons, in 1896 274,040 standard armored tons, without mentioning inferior armored tonnage and the armies to disembark on the Continent, she would turn the tide of victory to the other side.

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If no such unforeseen event occurs, and if the Dual Alliance neglects to seize its opportunity of 1896, leaving events to take their ordinary peaceful course, Italy will in all probability decline to renew the Triple Alliance treaty in 1897.

Germany and Austria-Hungary should be indissolubly united by common danger, but Italy is held with them solely by the incorrect assumption that France has designs against her and that French preparations are a menace; whereas the advantage to France in her real designs on her eastern frontier, and to the Dual Alliance, accruing from not having to divert or immobilize an army corps on the south, would be so great that every guarantee would be given against aggression if Italy would withdraw. All of Italy's interests are set against her remaining. The burdens, the expenditures required, and the commercial and financial policy of France, are already causing ruinous financial distress, which is entirely unnecessary. It is her natural, geographical prerogative, not yet appreciated, to reap alone the incalculable benefits of neutrality in the event of general European war. Her natural policy is that of isolation. She has nothing real to fear from either of the parties to the war, and no interests of hers conflict with theirs. It is true, as stated above, she would not object to an accession of territory from Austria, her old enemy, though now her ally, or even from France, particularly in northern Africa, yet her ambition for the present is satisfied while the process of unification and amelioration continues within. Further, a black, ominous cloud has recently risen above the horizon. She joined Germany and Austria-Hungary sure of perpetuating peace, to form an alliance that France could not dream of attacking. Now, however, France has found an ally and the Triple Alliance no longer is a guarantee of peace, for the Dual Alliance musters a strength that already preponderates, particularly on the sea, where Italy is most exposed, and whose preponderance is advancing with enormous strides. While Italy remains in the Triple Alliance, without British assurance, she faces the grim spectre of defeat. She would never have joined, she will probably not remain, in a Triple Alliance which has the Dual Alliance for an enemy.

Deserted by Italy, Germany and Austria-Hungary would lie helpless. In 1897 their 113,786 standard armored tons and 82,293 inferior armored tons would disappear like a breath before the 367,110 standard armored tons and the 266,000 inferior armored tons of the Dual Alliance. Their sea-coast would be ravaged, cities bombarded and ports blockaded against any supplies from without, while the invading armies, the first wave 1,416,000 strong, the total 6,630,000 strong, entering from the east and from the west, would overwhelm the 856,400 men in the first line of opposition and the 4,380,000 total.

The two nations in despair would cry out for British aid, and their cry would probably be heard, for the eyes of the British would be opened; they could not help seeing that the French and Russian armies unrestrained after Austro-German defeat would march unobstructed from Europe to the conquest of Egypt and India, even admitting that the British fleet kept a preponderance of force on sea. On Italy's withdrawal, the probability points to the formation of a new Triple Alliance of Germany, Austria-Hungary and Great Britain, the natural alliance of defense against the natural Dual Alliance of aggression. This Triple Alliance, formed on the expiration of the old in 1897, would oppose 387,826 standard armored tons and 432,883 inferior armored tons, against 367,110 standard and 266,000 inferior tons, about an equality in standard armored tons and a heavy preponderance in inferior armored tons. Great Britain, with her resources, could probably maintain an equality, if not a preponderance, by sea, though it would be a sore burden, as she would have practically no assistance from her allies. But the situation on land would remain hopeless. Assuming that the British troops would be found on the battlefields, the alliance, if now formed, would oppose in the first wave of war 1,075,800 men against an invading force of 1,416,000 men, and a total of 5,035,000 men against 6,630,000. This heavy preponderance will become greater each year, and ultimately would inevitably become utterly overwhelming, for the population of the one, 129,000,000, is increasing at the mean annual rate of .88 per cent., while the 165,000,000 of the other is increasing at the mean rate of 1.33, and this latter vast population does not count a dissenting voice in taxing its vast resources to the utmost, while the lesser population contains dangerous internal elements of division and weakness.

The withdrawal of Italy and the formation of the new Triple Alliance nevertheless would not probably be a signal for immediate war, though, as seen above, equilibrium would not exist. The aggressors would wait to allow the weakening elements of the enemy to work their way, recognizing their own strengthening unity of purpose. Italy would be offered inducements that would outweigh the advantages of spectatorship and neutrality. As mentioned above, the Dual Alliance would require but a light burden and would offer rich rewards. In the certain partition of Germany and Austria-Hungary that would follow she would be promised vast tracts around the Adriatic which, in the hands of an old enemy, have long been looked on with covetous eyes, and France, with vast, gratifying accessions on the east, might offer the old provinces of Nizza and Savoy, and might, perhaps, allow her to take Tunis and Tripoli, being sure herself of getting Egypt. With a certainty of victory, and fear of displeasing the powers that would, without her even, be victorious, she would probably pass from isolation to alliance. Europe would then see the six nations in the two great natural Triple Alliances: France, Russia and Italy for aggression; Germany, Austria-Hungary and Great Britain for defense.

Impatient aggression would not then have occasion to wait longer for further weakness in the enemy, having a preponderance on the sea of more than 100,000 standard armored tons, and, taking the present condition as an index, though each year will make a greater preponderance, on land an excess of 600,000 men for the first wave and 3,600,000 men total excess. This preponderance would be overwhelming. Signing the new aggressive alliance would sound the bugle-call to war. Europe would be seized with convulsions. Three nations would be engulfed in one great upheaval. Germany and Austria-Hungary would no longer be seen on the map; the British Empire would belong to past history.

It is evident which nation of the three victors would claim the East and take the largest share of the West. After the wrangle, a new era would begin in Europe. Its duration and its termination are easily seen. A glance at the map of history and the march of events shows that Russian ambition does not stop short of two continents, and will not be satisfied till Russian territory has no boundaries but oceans. After their intoxication, France and Italy would awaken in a nightmare; they would rush to alliance, but too late, they would be as children against a giant. A glance at the populations and their rates of increase leaves no hope for western civilization in its birthplace. Its young offspring across the ocean would be left alone to contest the high seas and redeem in part this error of history.

If, however, against probability, Italy renews the Triple Alliance treaty in 1897, Great Britain having continued isolated and the Dual Alliance having neglected to seize the opportunity offered in 1896-7, continuing thus the present status, the goal of the two races will still be not far off. The race by land is already practically won. The Dual Alliance can maintain preponderating armies guaranteeing victory with comparative ease, while the larger part of the increase of tax on the resources of the two nations would be devoted to the great race with Great Britain for preponderance on the seas. As seen above, it will be ahead in the race in 1896-7, at which moment both races will be won if it has the hardihood to bring them to a finish; but in 1898-99 the British fleets will reap the harvest sown in the last scare. Adding the Magnificent and Majestic and the seven new nearly similar first-class battle-ships laid down this year, seven of the nine in 1898, the other two in 1899,* a total tonnage of about 135,000, while the French add the Charlemagne, the St. Louis, and, by acceleration, the Henri IV., and a similar battle-ship not yet named, a total of 43,000 tons, and Russia adds one battle-ship similar to the Three Saints, and two similar to the Cisoi

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* A more recent programme reports ten of the Majestic class, five to be completed in 1897-98, and five in 1898-99; also six of about 6000 tons to follow shortly after.

Velikie, a total of 30,250 tons (Russia will add two powerful armored cruisers similar to the Rurik, of more than 12,000 tons each, which will make a heavy addition to inferior armored tonnage not here considered, since no addition will be made by the other powers), making a total for the Dual Alliance of 73,450 tons, about 61,500 tons less than the British additions, reducing the preponderance held in 1896-7 of 93,000 tons to 31,500 tons. The Dual Alliance thus will then still be ahead, with the chances of victory on both elements.

After 1898-9, beyond which estimates cannot now be made, the probability points to the Dual Alliance maintaining the preponderance, notwithstanding the vast resources of Great Britain and the intention of the British to maintain their force on a par, for, judging from the appropriations which have become enormous in France and Russia (in 1892 France provided for nearly $200,000,000 to be expended on new construction within ten years), it is the intention to tax to the limit the combined resources of the two nations. Consequently, when next year the French and Russian naval strength catches up with the British strength, the two races may be considered won whether the winner chooses war then or later.

III.

The future is thus gloomy for the essentially passive powers, whether the Dual Alliance has the boldness to adopt the most favorable plan or whether it awaits the ordinary course of events, which would probably consolidate the enemy. Is there any escape from this gloomy situation? Are there any methods of thwarting these plans? What can the passive powers do?

The same methods will thwart both plans. The surest and most desirable, the best method, would be the formation of a quadruple alliance of the passive powers, to take the offensive without delay. The force of this new alliance would heavily preponderate; on sea it would engulf the enemy. To accomplish this method, Great Britain would have to renounce her policy of isolation, which she is loth to do, and the treaty would have to embrace an offensive element, which would in all probability meet strenuous opposition from all the signatories. This method may consequently be considered as practically impossible.

The second best method would be for the Triple Alliance, though feigning defense, to take the offensive without delay. As seen above, the force of the Dual Alliance preponderates, though by land the preponderance is small; but, in case of adversity, British aid could be depended on, and the war would become general, as it would by the first method. But the treaty compact of the Triple Alliance is essentially one of defense only, particularly as far as Italy is concerned; consequently voluntary offense cannot be hoped for. Only by some unforeseen happening, causing the Dual Alliance to take a premature offensive attitude, could this method be realized.

There was some hope afforded by the attitude of the German Emperor last year,* in his determined efforts to strengthen without delay his own army, in his visiting both allies to review their forces, in his assembling his forces for their autumn manœuvres on the fields from which they will advance to battle, and in the tenor of all his utterances touching military affairs. It seemed that he recognized the situation, penetrated the future, saw the advantage, the necessity of action without delay, and was making preparation for bringing about the great issue. But subsequent events have dispelled this scanty hope, particularly the favorable reception of the Czar's overtures for commercial reciprocity.†

The third best method would be for Great Britain to take the offensive without delay. The Dual Alliance would be loth to accept the engagement in view of the advantages of postponement, particularly cool, calculating Russia, and it might be difficult to find a pretext; but there is always the open Eastern Question, and, with France, the question of African colonization, while among the French nation there is an over-confidence caused by the vista opened up during the exultations of Cronstadt and Toulon, which could no doubt be turned to advantage.

It would of course be best for her to attack the enemies one at a time, or one only, if possible. The best method would be to attack France, endeavoring to secure assurances from the Triple Alliance, or at least from Germany and Austria-Hungary, of participation in the event of Russia joining. Then it is not improbable that crafty Russia would decline to enter, notwithstanding her professions of alliance, for, as seen above, the two

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*Summer of 1893.

†A similar instance is found in the participation with Russia in interference with the recent treaty of peace between China and Japan.

allies combined would be overmatched by Great Britain alone. On the withdrawal of Russia there would be no reason for further execution of the war, for Great Britain has no fear from France except in her alliance with Russia. This move would effect the dissolution of the Dual Alliance. The eyes of the Frenchmen would be opened and they would renounce all idea of alliance with Russia.

The other method would be to attack Russia, seeking assurances from the Triple Alliance of participation in the event of France joining. There can be no doubt that France would be loyal and join. It is possible, on the other hand, if Russia is attacked on the Eastern Question, so important to Germany, so vital to Austria-Hungary, and then if she is joined by France, whom Italy is learning to hate and has brought herself to dread, that then the Triple Alliance might be induced to enter, notwithstanding the purely defensive nature of the alliance, and the general war so desirable might thus be brought about.

Great Britain stands toward Russia in standard armored tonnage in the ratio of about 3.66 to 1, and in inferior armored tonnage in the ratio of about 3.87 to 1; toward France she stands in standard armored tonnage in the ratio of about 1.81 to 1, and in inferior armored tonnage in the ratio of about 2.26 to 1. No doubt can be entertained as to the issue if either one alone is engaged. If the Triple Alliance joined Great Britain the combined force by sea of the four powers would stand toward the Dual Alliance in standard armored tonnage in the ratio of about 2.24 to 1, and in inferior armored tonnage in the ratio of about 1.92 to 1. The seas would be swept. On land, assuming that the British armies would be on the battlefields, a warranted assumption, since the seas would be clear and the troops would have allied soil to disembark on, the Quadruple Alliance would muster 1,335,000 men on the peace footing and 7,035,000 men on the war footing, while the Dual Alliance would muster 1,416,000 men on the peace footing, 6,630,000 men on the war footing. Considering the dispersion of the Russian army over a vast area and her separation from France, there is no doubt that the armies of the four allies would be found superior on the decisive battlefields.

If Great Britain attacked both parties to the Dual Alliance, a favorable opportunity would be offered the Triple Alliance for precipitating advantageously the inevitable conflict by land, and the probability points to the war being made general. But should the Triple Alliance decline to enter, and should Great Britain, in attacking one ally, be forced to engage both, even then, as seen above, the issue being essentially by sea, her unaided fleets would still throw a heavy preponderance against the allied fleets, in the proportion for standard armored tonnage, of about 1.22 to 1, and for inferior armored tonnage of about 1.43 to 1. Thus if Great Britain took the offensive without delay, the probability in all the events of war that could follow would mark her as victor, with an assured new lease of the sea and of the world's commerce.

Of the three desirable methods by which the war could be made general, while the passive powers preponderate in force and would act in unity, this one alone offers any grounds for hope. But this only hope is very scant, for Great Britain is loth to become a belligerent in European war and is slow to change her policies. With her vast commerce and shipping, she dreams of the riches which would come with neutrality when the Continent, hostile within, seeks its supplies from without, or of the choice of entering late in the conflict to decide its issue, bearing a small part of the burden and reaping a large part of the spoils. She realizes, too, that her daily bread comes over the water, that she would starve if its arrival were stopped for even a short while, and she sees the vast amount of her property that is on the high seas that would be exposed to a maritime enemy. She perceives that she has a monopoly already of the markets of distant lands, and that her colonial expansion continues to overshadow that of all the other nations. She enjoys prosperity and foresees its continuance with peace, and she looks with angry eye on any part that threatens to disturb peace where she might be involved. She would be loth, very loth, to take the offensive; she is slow, very slow, to discontinue her policy of isolation. The maxim has become general that she has all to lose by war. The maxim has not yet spread that she has all to save by war.

The fourth best method, the only one remaining, would be the formation of a defensive quadruple alliance, effected by Great Britain's joining the Triple Alliance without materially modifying the nature of the treaty stipulations.

The forces by land of the two alliances would not largely differ.

The slight preponderance, as seen above, would now rest with the four allies. On the sea, the Quadruple Alliance now has 480,439 standard armored tons against 215,952 standard armored tons of the Dual Alliance, and 471,312 inferior armored tons against 245,812 tons. In the event of war, the fleets of the Dual Alliance would be annihilated and the sea-coasts laid bare and colonies exposed. France could not dream of permitting such a state of affairs, even if she were sure of victory on land. Consequently, offense from the aggressive alliance would be out of the question. Even in 1896-7, at the moment of Great Britain's weakness, the Quadruple Alliance would offer 509,831 standard armored tons against 367,110, and 481,972 inferior armored tons against 266,000. England would in all probability come to the financial relief of Italy, and with her untold wealth could probably maintain a preponderance of force by sea in favor of the Quadruple Alliance, while the continental powers strained their energies to keep the armies on a par. Peace would be insured for many years, and another generation might pass before the conflagration came.

The Dual Alliance, however, would not think of renouncing its passions and its schemes of conquest, and a pitiless, relentless peace struggle would begin on a scale undreamed of even in this day of crushing armaments. There is no doubt that the Quadruple Alliance could maintain a preponderance for many, many years, though in nothing like the present proportion, if all its members bent their energies in accord to that effect. But while in France and Russia there is but one national purpose, without an opposing voice from man, woman or child, in Germany there is a growing socialistic disaffection, in Austria-Hungary there is dangerous internal dissension among the heterogeneous population, and Italy is wailing in financial distress.

The 165,000,000 of souls, united in one purpose in France and Russia, are increasing at the mean annual rate of 1.33 per cent., the 39,000,000 French at the rate of .32 (the mean for 20 years, 1871-91), and the 126,000,000 Russians at the rate of 1.64 (the mean from 1867 to 1886), while the 160,000,000 souls with dissenting voices in the Quadruple Alliance are increasing at the mean annual rate of only .83 per cent., the 50,000,000 Germans at the rate of .98 (the mean from 1875 to 1890), the 41,000,000 of Austria-Hungary at the rate of .76 (the mean from 1870 to 1890), the 31,000,000 Italians at the rate of .62 (the rate in 1881), and the 38,000,000 British at the rate of .917 (the mean from 1871 to 1891). It is evident which alliance would win the race in growth of armies.

In sea power Austria-Hungary has not and will not figure. Italy is barely holding her own. For new construction her appropriation has passed from $6,500,000 for the year 1890-91, $5,600,000 for 1891-92, $4,900,000 for 1892-93, to $4,900,000 in 1893-94, while it is estimated at $4,900,000 for the current year 1894-95. Germany, straining every nerve for her armies, is neglecting her navy. Her appropriation for new construction has rapidly and steadily decreased from $8,500,000 in 1891-92, $6,900,000 in 1892-93, to $4,600,000 in 1893-94, and it is estimated at $3,300,000 for the current year 1894-95. On the other hand, both France and Russia are making steady, unparalleled additions. The French appropriation for new construction has risen from $11,600,000 in 1890-91, $13,600,000 in 1891-92, $13,600,000 in 1892-93, to $14,200,000 in 1893-94, and it is estimated at $14,800,000 for the current year 1894-95; and the Russian appropriation has risen from $7,500,000 in 1890-91, $9,500,000 in 1891-92, $10,400,000 in 1892-93, to $11,100,000 in 1893-94, and is estimated at $11,000,000 for the current year 1894-95.

The total appropriation of the Triple Alliance (not taking account of Austria-Hungary) for new construction in 1890-91 was $17,900,000, while that of the Dual Alliance was $19,100,000. For the current year the estimates for the Triple Alliance are $8,100,000, a falling off since 1890-91 of $9,800,000, and for the Dual Alliance they are $25,800,000, an increase since 1890-91 of $6,700,000. The excess for the Dual Alliance was $2,200,000 in 1890-91; to-day it is $17,700,000.

The British additions have fluctuated by reason of the oscillatory programmes of construction. The mean annual appropriation for new construction since 1888-89 (the year previous to the Naval Defense Act) has been $21,700,000. For the current year it is estimated at $23,400,000.

Thus the total appropriation for new construction has been somewhat larger for the Quadruple Alliance, though it has been on a constant decrease, while that of the Dual Alliance has been steadily increasing. Preponderance, though in nothing like the present proportion, would no doubt be maintained as long as the alliance remained intact.

Thus the peace struggle would continue till Italy, for the reasons mentioned above, impoverished, if not utterly bankrupt, from the burden laid upon her, fearing the approach of the day of sharing defeat on land with her allies, threatened and allured by the menacing enemy, perceiving the prerogative of her position, withdraws, either to remain a spectator and reap the benefits of neutrality, or to join the Dual Alliance and share the spoils of victory. The day Italy withdrew, equilibrium would be broken, the balance would drop with a thud to the side of the aggressive party. The great war struggle would be at hand, with forlorn outlook.

At first sight this method of postponement might appear to offer an opportunity for allowing time to alter the sentiment in France, to open the eyes of Frenchmen and cause them to abandon the alliance with Russia, and join their brother nations in one united body, to throw out of Europe the universally threatening Slavic race, and restrict Russian ambition to Asia, to the hardy task of supplanting the stagnant races of the East, or of forming a barrier between Europe and those hordes that may some day become warlike, while in peaceful Europe, where a small common standing army could easily defend a single eastern frontier, the brotherhood of the higher nations of western civilization, reasonably adopting universal arbitration, could divert the national resources to the universal betterment of the conditions of life, to regulating the colonization by their own superior races of the unoccupied portions of the earth, and to arranging for humanely supplanting or exterminating, if it is impossible to elevate, the inferior races, to regulating, in sum, in the best way, the affairs of our planet.

But this dream of Utopia is inconsistent in our world of universal struggle, and cannot for a moment be indulged in broad daylight by any one acquainted with Frenchmen, nor to any one familiar with the domestic, scholastic and military education of the French could there be any hope for the coming generation which will not have seen the days of 1870-71. Besides, the alliance with Russia, which, to a spectator, seems so unnatural, is, as stated above, a most natural one to Frenchmen, whose shame and passion hide ultimate interests by immediate ones. There are no doubt moments of calm and reaction in many thoughtful French minds, when undefined questionings come as to what lies beyond the glorious vista; as to what real fellowship can exist between two types of races, occupying widely different rounds on the ladder of civilization; beween two governments, one of freedom and one of despotism; that after all the affection displayed by Russia, she can care for them only as temporary instruments, coolly using their forces, their generosity, their passions for inexorable plans of conquest that would in next turn take in without hope of resistance their own lovely country, or else might, after the overthrow of Great Britain, principally by French fleets, and the accession of India, sufficient for temporary expansion, abandon France, with her strong passions and thirsts still unsatisfied, and leaving her thus with no rewards except a necessary opening for colonization, which is already larger than the requirements of the nation, weakened by conflict, to stand again alone against the central powers, while she, in her turn, prepared for the great game of European conquest, for the time when the dissenting western nations should cripple themselves and exhaust their forces in war with each other.

But these undefined misgivings or questionings are stifled and would never be uttered for fear of incurring the accusation of a want of patriotism, the most reproachful accusation that could be made in France. No, the only way to dissolve the Dual Alliance is to put Russia to the test of sharing defeat with France. Great Britain alone can apply this test.

It seems hard that France can be saved only by defeat. This great, brave, chivalric nation has suffered for humanity all down history. Defeat at the hands of an old enemy, and the renunciation of the bright hopes for revenge on the other old enemy, would be the severest of all the martyrdoms yet demanded of beautiful France; but the price even then would be small if it redeemed her, and saved her at the same time that it saved Europe from ultimate destruction at the hands of the too powerful young giant, standing club in hand, with threatening and determined brow, knocking at the door of higher western civilization. As seen above, however, there is little hope of this salvation. The hope is somewhat greater, though still small, that the fourth and least desirable method, the formation of a defensive Quadruple Alliance, may be realized. As seen above, the policy of isolation has been a natural one and is a stubborn one with Great Britain, yet the forces will set toward a renunciation as her relative weakness becomes more and more evident. If the nation could be familiarized with the real relative strength of fleets, estimated rationally by separating standard from inferior tonnage, at the present moment and during the years to come, there is no doubt refuge would be sought in the Triple Alliance, and there would even be a glimmer of hope for her taking the immediate offensive.

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Thus, in conclusion, in studying the situation and outlook in Europe, the dominating fact, towering above all others, is the alliance of the two great aggressive nations, France and Russia, who count more than half of the entire population that regulates European affairs.

Though French aggression is principally from passion, strong, natural, inherited, injured, and only partially from ambition for expansion, while Russian aggression is almost wholly from ambition for expansion and but very slightly from passion and fanaticism, yet both aggressors aim at the same enemies. The overthrow of Great Britain and the conquest of Germany and Austria-Hungary would satiate even French passion, while the consequent opening up for expansion over central and southeastern Europe, over Asia and into Africa, would overflow the banks of even Russia's boundless ambition.

The natural designs of the alliance are stupendous, defying almost the imagination itself. Its possibilities are fairly boundless, covering a hemisphere. If fully realized, they will change utterly the face of three continents.

The feature of the alliance which most imposes itself on the mind of the observer is the formidable force it musters and the amazing rapidity with which this force has recently grown and continues to grow. In the two great factors necessary for great armaments, wealth and population, its resources are fairly inexhaustible, France having the wealth and a boundless generosity toward Russia, and Russia having the population. The powers of the Triple Alliance, on the other hand, which until recently increased their forces apace, have now lagged far behind. From 1890 to 1894 the entire standing armies of the three allies have been increased by only 71,000 men and the force on the war footing by 320,000 men, while the French and Russian standing armies have been increased by 139,400 men and the force on the war footing by the enormous figure of 1,330,000 men. The aggregate appropriations for additions to the naval forces of Germany and Italy (the small appropriations by Austria are not considered), during the last four years, amount to $43,600,000, while those for France and Russia amount to $98,200,000. Thus the total additions to the land forces have been in the proportion of 3.76 to 1, and the total appropriations for additions to the naval forces in the proportion of 2.25 to 1, and each successive year has seen the disproportion between the additions become greater. The additions to the strength of the Dual Alliance are steadily increasing, those of the Triple Alliance are steadily decreasing. The maximum strength of the latter has been reached, its resources are taxed to their limit. The maximum for the former is not yet in sight, and as far as can be seen has no limit. The stationary force has now already been passed by the one that continues to advance with great strides; each day sees the gap between them widen, increases the probability and the disaster of defeat.

Great Britain, during the last four years, has appropriated for new naval construction $87,200,000, $11,000,000 less than the Dual Alliance. She intends, no doubt, to maintain a force as far as possible equal to that of the two allies combined, but, as explained above, the different methods in the shipbuilding programmes of the three countries and the coincidences, concerted or unconcerted, in the times for laying down new vessels, cause the British force to be now at a marked maximum of strength and to approach an inevitably low minimum in 1896-7.

On examining further into the internal condition of the two parties the sight becomes alarming. Distressing division exists among the passive powers and becomes more distressing each day. Great Britain is isolated, and Italy, in financial distress, tends strongly toward withdrawing from alliance with Germany and Austria-Hungary. Germany is rent internally, and prevented from developing her whole strength by disaffection, identified more or less with socialistic growth, the outcome to a large extent of the burden imposed by a heavy armament where, after victory, there is not the offset of active incentive or burning passion. The military bill last summer was a symptom. It required the dissolution of the Reichstag and the use of all the influence of the sovereign over a most loyal nation to procure its passage. Austria-Hungary has internally, in the dissensions of its heterogeneous and widely different races, all the elements, indications and symptoms of dissolution, and Russian influence is undermining the loyalty of the Slavic element of the army as of the population.* France and Russia are standing closely united before an almost hopelessly divided enemy.

To darken still more the gloom of the horizon, the passive powers, dedicated to peace, oppose taking the offensive themselves and will allow the aggressor to choose his own time and method of attack. The present is supremely the opportune moment for the passive powers; a future time will be for the aggressors, who are now crying out peace, peace. This cry of peace means "Peace till my weapons are sharpened," while the passive powers appear blindly to think that it means enduring peace, a contradiction to the very nature of the two powers and their alliance.

Fate or forethought will have the Franco-Russian strength reach its maximum preponderance over British strength previous to the expiration of the treaty of the Triple Alliance. Italy will, in all probability, have decided not to renew the alliance though still being in it, which will prevent the shaking up of the powers and the formation of a new natural Triple Alliance, thus depriving Great Britain of the chances of having German and Austrian aid, while, in all probability, she would, on the verge of disastrous war, applying at the eleventh hour, be refused refuge in the Triple Alliance.

After Great Britain's overthrow and Italy's withdrawal following it, Germany and Austria-Hungary would be an easy conquest, whether Italy chose to join with the conquerors or not.

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On examining further into the events to follow the fulfillment of the aggressors' stupendous designs, whether realized easily as just indicated or by one of the other probable ways previously discussed, the situation takes on an awful aspect.

How would the spoils of three continents be divided by France and Russia?

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*Recent reports have it that Austria-Hungary has been induced by arguments or threats into taking steps towards abandoning the alliance with Germany, her natural alliance, her only possible hope.

The population of France is less than 39,000,000; that of Russia more than 127,000,000. The French population has been increasing over a lapse of fifteen years (from 1876 to 1891) at the mean average annual rate of only .32 per cent.; the Russian population has been increasing over a lapse of twenty years (from 1867 to 1886) at the mean average annual rate of 1.64 per cent. The Russian population is thus nearly 3¼ times as large as the French, and is increasing four times as rapidly. (During the last fifteen years the rate of increase in France has been on a steady decrease; it had fallen from .500 in 1876 to .065 in 1891. At the latter rate Russian increase is twenty-three times as great.)

French temperament is and has long been strongly opposed to colonization. The Frenchmen who leave France usually return. France does not care for large increase of colonial territory, and would be content with but a small share of German territory, while Russia is steadily expanding at a rate not approached by Rome when she was advancing to her conquest of the world.

For the coming war, passion dominates in the bosom of the Frenchman, who is looking for revenge; ambition animates the Russian, who is looking to extension of Slavic sway.

Thus it is evident that to Russia would fall the vast territory on two if not on three continents.

If Italy should sit at the feast of victory, which she may do, she would be satisfied and well pleased with a comparatively meagre morsel of the spoils, a modest part of the territory now belonging to Austria and some territory in Africa.

After the feast, France and Italy would perceive that they had waged the fratricidal war in the interests of a power, then ready, inevitably, after a short time, to swallow them also, both at a time or singly.

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To check this sombre, onward rush of events there are no means on which much hope can be placed. The great, best remedy, the dissolution of the Dual Alliance, does not permit hope. This alliance, founded on complete community of immediate interests, is come to stay, and is growing stronger and more indissoluble each day. Only disastrous war, realized or imminently threatening, can dissolve it. No combination in Europe without Great Britain's sea power could threaten or inflict such war. This sea power at the present moment could do so alone, but the opportunity is rapidly passing away. There is scarcely a shadow of hope that Great Britain will take the offensive; there is but the barest hope that she will throw her power into the Triple Alliance to save herself and it. This Alliance itself, from the very nature of its exclusively defensive compact, cannot, while the Dual Alliance cries peace, take the offensive and insure the later joining of the British sea power in the event of adversity.

Thus the entire responsibility rests with Great Britain, and the necessity is urgent for her immediate action. Each day sees the vessels building in France and Russia nearing completion. Fifteen months hence the preponderance of power will have passed over to the enemy; the Dual Alliance will be beyond the possibility of dissolution; the one opportunity for saving herself and Europe from the dread consequences of this alliance will have passed forever. Each day will then bring nearer the day of her greatest exposure to a stronger aggressive enemy; each day will render less probable her acceptance into the refuge of the Triple Alliance; each day will render more inevitable the desertion of Italy and her passing over to the enemy.

If self-sufficiency, or conservatism, or want of enlightenment, or of foresight, or lack of decision, or boldness, or all combined, cause Great Britain to neglect the call of duty from the crisis in her own and in the world's history; if she fails soon to throw her fleets against the enemy, neglecting to choose war while she is stronger and while the enemy could be disintegrated, leaving the enemy to choose it when he becomes the stronger and indissolubly united, and if she fails also to adopt the less desirable but only other alternative of seeking refuge in the Triple Alliance in time for acceptance and in time to save Italy, thus leaving the road clear for the plans of the great aggressive alliance, then may Heaven prepare to come down on earth to work miracles by the hands of men, may a host of guardian angels hover close over freedom and civilization as they tremble in the lands of their birth.

"LAGUERRE."

DISCUSSION.

LORD GEORGE HAMILTON.*—A perusal of the pamphlet entitled "An Introduction to the Study of Coming War" is very interesting to an Englishman, as giving the views and deductions of an outside authority upon the present and future strength of the British Navy relatively to that of France and Russia. The writer has treated the subject entirely from a statistical and arithmetical standpoint, arbitrarily dividing ships into two categories, "Standard armored tonnage" and "Inferior armored tonnage." He treats every ton of each class as an equal fighting unit and then makes up the totals of these units. On this assumption he draws wholesale conclusions very much to the disadvantage of Great Britain. In my judgment, this method of gauging the fighting power of a fleet is fallacious, even if the classification were sound. To take a large number of ships varying in size from 12,000 to 6,000 tons, and of every conceivable shape, some turret, some barbette, some high freeboard, some low, some heavily armored vertically, others relying on horizontal armor, and to assume that every individual ton of every different ship represents an equal fighting force is a self-evidently erroneous proposition. But the classification of what is "standard armored tonnage" and what is "inferior" is also faulty. If the age of a ship is to be the governing factor as to whether it is "standard tonnage" or "inferior tonnage," the age of a ship must date from the time she is laid down, and not from the date of her launch. British vessels are built and completed much more rapidly than foreign vessels, and this celerity of construction is as remarkable before launching as afterwards.

A vessel has merely to remain for a long period on the stocks unlaunched to become, according to the principle of classification adopted, a superior fighting ship to one laid down after her but launched before her. The method, both of classification and addition, adopted operates unfairly so far as the existing fighting power of the British fleet is concerned. As regards the future, the conclusions of the writer are based on inaccurate information as to the condition and progress of the big ships building in the different dockyards of Russia, France and Great Britain. It is assumed that by December, 1896, France will have added seven big battleships to her fleet—Russia eight. To divide these numbers by half is a more correct estimate of the probable state of the ships eighteen months hence from their known condition now. Whilst the two navies above mentioned have their additions greatly exaggerated, a corresponding depreciation is made of the reinforcements of the English navy during the same period. There are now 10 ships of far larger dimensions than are building in foreign yards, in various stages of construction. It is assumed that of these 10 the

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* Lord George Francis Hamilton, at present Secretary of State for India, formerly Secretary of State for the Navy, framer of the Naval Defense Act of 1889.

Renown only will be ready by December, 1896, and the Magnificent and Majestic by the end of 1897. The estimates presented to the House of Commons show that the Magnificent and Majestic will be completed by July, 1896, and the Renown shortly afterwards. If the acceleration of the remaining seven vessels became of real importance they would, one and all, be completed by the end of 1897.

The idea that Great Britain is in a trap for the next two years is an illusion. Whilst criticising the general principle advanced in this pamphlet, the contentions entertained in it are very valuable to Naval Administrators, as evincing the necessity of a continuous and uninterrupted addition year by year to a fleet of those big fighting vessels upon whose numbers the supremacy of the sea alone depends

Captain H. C. TAYLOR. U. S. N.—It is not easy to discuss Mr. Hobson's essay in a brief or superficial manner.

He is very sweeping in his arguments, and they are so ably sustained as to deserve an amount of thought and study scarcely to be looked for in any ordinary criticism or discussion.

Logically Mr. Hobson is correct; the conditions he lays down are those that appear to exist in Europe at the present time, and the deductions he draws from their existence are accurate. Nor can we say with any positiveness that his forecast of the future situation may not be confirmed within the next quarter of a century.

The difficulty with such problems as these, which occupy so wide a field of thought, is that no matter how logical the reasoning may be the premises upon which our logic is based may themselves be defective, and for the reason that with ordinary human discernment we cannot recognize all the growing national influences now existing unless they have attracted our notice already by visible action and striking effects.

Among the students of modern history there are some who claim to perceive in southeastern Europe a nascent force which promises to be for centuries to come a thorn in the side of Muscovite dominion. The national spirit now stirring there, unnoticed save by a few, may include the states of Servia, Bulgaria, Roumania and the adjacent principalities. The nation thus formed would be the natural heir of the Turk in Europe and of Austria-Hungary's eastern provinces, and its extension to the north and northwest would, in a measure, depend upon the degree of exhaustion of Russia and Austria in the next great European struggle.

This budding state would command the outlet of the Black Sea and dominate the Adriatic and Levant. Its youthful vigor would utilize to the fullest extent the great military and naval strength of the Balkan peninsula, whose strategic qualities have been almost forgotten by the decrepit government of the Sultan. The opportunity and signal for its birth would be the outbreak of those mighty conflicts which our essayist clearly discerns in the near future.

This empire of the Balkans, or by whatever name it shall be known in history, will be always on the flank of Russia's westerly advance across

Europe. Its strategic position will compel her anxious attention in case of war. Something more than an army corps will be needed to contain or observe the army of the new state and to mask its influence in the theater of war. It must be attacked directly and by Russia's principal armies, which in so doing must expose their flank to western Europe. Its fleet will not be so easy to prepare as its armies, for the nucleus of the latter exists already. Its naval strength once developed, however, would be exerted from a position of great strategic value in the event of a determined contest between the Dual and Triple Alliances. Details are purposely avoided, for it is not claimed that immediate war would find this nationality sufficiently crystalized for action; but should some years elapse before the deciding blows are struck its influence will probably be felt. Our first answer to the essayist's question of what is left for the passive powers of Europe to do against the impending onrush of the Gaul and Muscovite would therefore be that England and the Triple Alliance should devote their skill in diplomacy to encouraging those southeastern states to prepare for union, independence and a strong army and navy, and to educating them to understand their future destiny as a factor in European affairs.

There is yet another latent force in Europe which, if developed into activity, would exert a powerful influence upon the situation as described by Mr. Hobson. This force is Spain, if it shall once awaken from its long sleep. The elements of greatness exist in Spain to-day. The national spirit has been at times subdued but never destroyed. Signs of its revival are apparent to those who examine closely. Commerce and industries begin to develop at Barcelona and elsewhere. It has already the nucleus of a respectable army and navy and is developing ambitions as to Morocco. Should this revival continue and prove to be solidly based we should soon have to take into consideration the excellent strategic situation of the Iberian peninsula.

Knowing that Spain is not dead, but only sleeping; recognizing her compact and isolated nationality, we ought always to expect a future renewal of her greatness. It is probable that such a renewal would be marked in its earlier stages by the absorption of Morocco, the strengthening of her posts in the Balearic Islands and by a rapid increase of army and fleet. We can easily imagine in such a contingency how strong would be the influence at sea of this reviving power in the western Mediterranean, and how hazardous it would be for French armies to undertake distant campaigns against the Triple Alliance while hostile Spanish columns awaited in the passes of the Pyrenees the signal to advance upon Bordeaux and Toulouse.

In further reply, therefore, to Mr. Hobson's inquiry as to what the passive powers can do, I suggest that they can encourage Spain to absorb Morocco and to strengthen her military and naval force. England can assist her finances, now much involved, and her industrial development.

Spain can in fact be put upon her feet by the passive powers and her developed strength and exceptional strategic position would weigh too heavily in the scale to be disregarded by any combination.

Spain then can be made very quickly a powerful clog upon the wheels of the Dual Alliance, while with longer time for naval preparation the Balkan empire or republic might become an almost impassable obstacle in the path.

These suggestions are not put forward to controvert Mr. Hobson's arguments, but to introduce other elements in the discussion which perhaps have a place there and which may modify somewhat the conditions of his problem.

It is doubtful if in any case events would move as rapidly as the essayist believes. It takes much time to overcome the spirit of nationality, even after a nation is subdued and overrun. If the years in the essay were decades and decades were centuries it would seem to some members of the Institute a reasonable forecast; for when we think of the past history of these countries and note how irresistibly the waves of Eastern nations have moved westward across Europe until their force has been spent, it is natural to believe that in the future this phenomenon may be repeated.

Commander C. F. GOODRICH, U. S. N —The writer has given, to help us, in speaking of the elements of naval force, some definitions which will doubtless meet with general acceptation, for they express tersely what would ordinarily require long verbal circumlocutions. His *standard* and *inferior armored ton* are indeed welcome terms. I could wish that he had suggested a similar happy measure for *quality* of armored tonnage. This is implied, but not so clearly stated as it must have been in his own mind.

I think this essay an ingenious speculation in European politics, although I am unable to accept its postulates or its conclusions. There is, so far as I know, no evidence of a wave of Slavonic invasion sweeping westward as argued. Indeed, the late Czar will be longest and best remembered for his steady and successful determination to preserve peace at all hazards. His successor's policy is not likely to be greatly different, for his attention will be largely compelled to internal questions.

The writer's apprehension of immediate war seems to be based on Russian desire for territorial aggrandizement, aided by French thirst for revenge. It is not improbable that cool heads in Russia have not yet forgotten how difficult and relatively fruitless was the war with Turkey in 1878. There is nothing in the history of that campaign to show the possibility of equipping and putting into the field a tithe of the total available force now borne on Russian paper. It is but fair to subject all similar estimates to equivalent reductions, leaving, of course, the relative numbers about as stated. The absolute numbers I am not in a position to verify, nor is their truth, which is not questioned, essential to the main contention.

That Russia covets Constantinople, and that she will eventually obtain it, is doubtless correct. But this indicates a specific, not a general, scheme of expansion. The same holds good for the eastern outlet which she seeks, with due pertinacity, in Korea. The invasion of India is a movement she cannot undertake at the same time with either of the other two; nor does it, at any moment, offer much chance of success against the large and well trained force in India of British Imperial and Indian troops. Personally I have never understood the fear expressed and felt by many Englishmen on that score. Judicious handling of the Afghans will secure an efficient buffer on the western frontier of India, while a glance at any good map will make clear the slight hope of victorious advance toward Peshawur from the northwest.

Egypt is not to be taken from England's grasp by any army however strong until her command of the sea is destroyed. Now naval warfare is not entirely a question of numerical contrast. Lord Nelson was always willing to fight the French even when they were slightly superior in numbers. And he was right, as the battles of St. Vincent, Aboukir and Trafalgar testify. There can be no doubt in the minds of disinterested critics that the sea habit of the English will always give them a decided advantage over the French, with tonnage, armor and guns equal. We can readily compare numbers, but to evaluate *morale* is no light matter. The persistent keeping of the sea, the constant, never-ceasing drilling and manœuvring of squadrons have fitted the English to enter into their next naval war with a confidence born of practical familiarity with their weapons.

It is stated that in 1896-7 the Dual Alliance will have, in standard tonnage, 1.21 ton to England's 1.00. Apart from the difficulty which France and Russia would encounter in effecting a junction of their fleets, this proportion should occasion no paroxysm of alarm to Englishmen, who have fought and won against as heavy odds. After all, I feel confident that those who guide the destinies of Europe are well aware of the great possibility of defeat, even when somewhat numerically superior to England, and that they will be slow to risk a naval campaign on an equation where two and two do not necessarily make four.

One matter is omitted from this very thoughtful essay which appears to me vital. Of course, such numbers as 1,416,000 to 856,400, to be followed by a total of 6,630,000 to 4,380,000, are not to be taken *au pied de la lettre*, but rather as indicating a rough proportion between what will, confessedly, be huge and opposing masses; but, after the most liberal allowance made for exaggeration in these estimates, there will remain armies of a magnitude almost inconceivable. The question at once arises, how and by whom shall these armies be supported and supplied? The days of living off invaded country have passed away, and so money for these suggested enterprises must be found. France might raise enough for her own needs by national subscription, although the interest charge in her annual budget is already appalling in size, and national schemes are less popular than before the days of Panama. But Russia is poor and must go to the Jews. Will they advance the requisite cash? Herein opinions may properly differ. Mine is that such a request would meet with a firm and final refusal.

It appears to me that the existence of a Russian wish to overrun

Europe first and the rest of the Eastern hemisphere afterwards is stated rather than proved. Without the absolute certainty of Russian co-operation France will sigh in vain for *revanche*, Alsace and Lorraine, and probably our cousins across the water, while keeping a careful eye on the weather, can, for a time yet, sleep peacefully, undisturbed by dreams of universal war, and this notwithstanding the hatred of the Frenchman for the Englishman—far greater than that he bears towards the German—and notwithstanding, too, the menace to peace in the complications likely to spring out of the Simonoseki Treaty.

Mr. W. Laird Clowes.—With respect to the interesting paper of Mr. Richmond Pearson Hobson I should like to say that the author appears to take a far too pessimistic view of the situation in Europe. It is true that everything points to the probability that sooner or later the Triple Alliance must break up, and that we shall witness alliance and co-operation between those fellow-Latins and natural allies, France and Italy; but, on the other hand, I cannot admit that the unnatural pact between France and Russia is likely to continue. The fate eventually reserved for Russia seems to be isolation, in Europe at all events. Nor does the writer take a sufficiently rosy survey of the progress of the British naval preparations. He says that the Magnificent and Majestic, for example, cannot be hoped for before the end of 1897. I hope that we shall see both of them in commission before the end of the present year, and that the Renown and at least one of the still newer battle-ships will be ready next year. At the same time I grant that we are not going ahead as fast as considerations of prudence should dictate, and that unless we accelerate our rate of progress we stand in danger of sooner or later falling out of the race with the Dual Alliance. Yet, believe me, we shall put on the necessary spurt in time. We are not situated as you, our cousins, are. We have no large inland territories which can only with the greatest difficulty be induced to realize the value and importance of a strong navy. All our population is quite solid upon that one question if upon no other. We do care for that point; but I don't think that we care much for the European situation, save so far as it may directly affect or threaten our immediate interests. Nor do we, I think, dream of European alliances. There is only one alliance, a strictly anti-aggressive one, that would be really popular here, and that is an alliance, in the interests of general trade and peace, of the whole Anglo-Saxon race. Mr. Hobson does not touch upon such a consideration as a possible factor in the moulding of the world's future. It is nevertheless a consideration which is forcing itself before the attention of thoughtful men on both sides of the Atlantic. The man who, on your side, hasn't traveled fifty miles outside Hugginsville, and the man who on our side hasn't traveled fifty miles outside Little Peddlington, won't listen to a suggestion of such a consummation; but these are not the gentlemen who direct affairs, thank God! Every Englishman who spends a few months occasionally with his hospitable American cousins, and, I hope and believe, every American who either comes here or who travels a bit about the world and takes intelligent notice of what his race and ours has done and is doing, sees whither the common interests are drifting. You have cut loose from the home strings, and certainly no one here blames you for having done so; yet, although you have cut loose, you have the same ancestry and the same blood, and may heaven give you one day a part in the common inheritance, in defense of which I look to see all our kin ere I die stand together. Surely we can both observe and cherish our national allegiance without forgetting, in the stress of honorable rivalry, that we owe some racial allegiance as well. If only every Briton could see the United States, and every American could see the British Empire, the petty and passing jealousies of the two great branches of the family would be quickly swallowed up in a desire for co-operation and mutual help and in generous pride in the family prosperity.

Lieutenant C. N. ATWATER, U. S. N.—To those interested in the study of the world's politics from a military standpoint the vigorous and novel views set forth by the essayist are worthy of attention. Probably few officers will entirely agree with these views. It is safe to say that a majority will find that they are extreme. But a debt of gratitude is due the essayist for opening up, as a new subject of discussion for the Institute, the treatment, from a naval standpoint, of international politics. While articles of a character similar to this one abound in the British reviews, they are conspicuously absent from periodicals on this side of the Atlantic, and in breaking ground in what is for us a new field the essayist turns a furrow both broad and deep. It would seem to be a duty for the handful of commissioned officers of our army and navy—thirty-five hundred of the seventy millions of our population—to discuss and to keep discussing the war politics of the world. They are the nation's only trained technical students in military matters, and when questions vast enough to involve the welfare of the whole civilized world are at stake they should have opinions as to what the possible results may be.

The essayist refers to the rare opportunity the coming war will offer the United States to take her place among the world's carriers and attract wealth to herself instead of paying heavily to get her goods to foreign markets. Then, indeed, will she "be in a position to begin immediately on her ultimate naval policy . . . if she has sufficient power afloat during the war to enforce respect for her rights as a neutral." But is she likely to have such power when it is needed? Is she not more likely, if things move as usual, to be ready to get into difficulties at the moment when a decisive stand, backed by force, would secure her freedom to reap whatever benefits an armed neutrality might confer? Weakness may even force her to take part as a combatant in the struggle, for her children are not patient when put upon. As a foreign writer has recently said, "The Americans are known to act regardless of consequences." Admitting that the affairs of Europe are in a desperate condition, that condition may mean more of danger than of profit for us. We are not ready for war. We are rich and relatively defenseless. Why may not the overburdened Continent, laying aside its differences, create a diversion by attacking and despoiling us? We, like our European neighbors, are controlled by interest, and our interests clash with theirs to our betterment. They certainly do not love us enough to fight for us, and that some of them would enjoy seeing us humbled there can be but little doubt. The United States alone among the great nations can afford to consider military power as of secondary importance, but even she cannot safely assume that she may not be forced to fight. With her millions of aggressively patriotic citizens ready to cry war with a sure voice whenever there is a show of provocation, she should reflect, when she interferes in the affairs of the nations, whether her forty thousand soldiers and sailors are strong enough to enforce her demands and ensure her safety. If she cannot be content to stand modestly back from the front rank of the powers, she should lose no time in preparing for war by strengthening her fleet and the defenses of her waterways and coast cities.

The essayist has quite a startling array of figures marshaled in support of his views as to what may happen abroad, but it is questionable if the preponderance of the fleet of the Dual Alliance will be as great in 1896 as it is made to appear on paper. The value of other than battleships is not sufficiently emphasized, while such other factors as fortified coaling stations, torpedo fleets, merchant tonnage, the supply of trained seamen and the possession of great wealth are either not dwelt upon or not mentioned. If, indeed, Great Britain hesitates to ensure her sea power by spending upon it a larger proportion of her enormous wealth, at the same time that the Dual Alliance continues to advance in fleet building, it may be foreseen that she runs a risk of losing her sea power somewhere in the twentieth century; but that she will neglect to provide against the danger does not seem very probable. Those who have been expecting the outbreak of the "imminent" European war ever since Russia and Turkey came to blows over the Eastern Question have little faith in predictions as to when it will begin, what will cause it, or what sides will be taken by the nations concerned.

It seems to me that the essayist has allowed himself to make a bugbear of the Slavonic race. He is so earnest that he occupies the ground of those English Russophobes who find it necessary to alarm their countrymen in order to secure money for the defense of the empire, and he goes even farther than they do, for where they see menaced a single nation, and that their own, he regards the whole civilization of western Europe as in danger. He seems to see issuing from Russia's vast territory barbaric hordes, like unto those of Attila or Timour, which must inevitably flow over Europe to the destruction of the liberties, arts and sciences which go to make up our civilization. But modern Russia is not really a spectre before whose unmeasured and superhuman power the West need tremble. Her barbarism is rapidly giving way to the western civilization she is supposed to threaten, and if she changes the present political boundaries of Europe it will not be to lay waste the nations with fire and sword.

As lookers-on we Americans have neither bitter animosity nor overheated affection for any outside nation. As the essayist points out, interest rather than sentiment controls modern policy. Among our naval officers Russia will find her champions as against England, France as against Germany, and the reverse is equally true. Individual officers may prefer one nation to another, but as a class we champion no power but our own.

Asst. Naval Constructor HOBSON.—The paper above was prepared in the spring and early summer of '94. Since then an international event of the first magnitude has taken place: a war has been entered into, prosecuted and concluded.

History presents few cases of war—the gravest phenomenon that takes place on our planet—where the consequences promised to be more grave, more far-reaching. Apart from the vast economic, sociological and ethnical vistas opened up, in which speculation loses itself, the political situation and outlook in Europe have been profoundly influenced. A power has been added to the list of Russia's enemies, which acts with tremendous leverage on Europe.

Japan has finally closed the war under such circumstances that no fact is so universally recognized as the approach of an inevitable struggle with Russia; on this fact the eye of the nation is centered, and with it in view, the national policy will be shaped and the national resources plied.

Moreover, a strong fleet, being the first essential, will be the first aim of the policy. This fact is of capital importance to Europe, whose immediate destiny hangs over the sea, wrapt about by the British fleets; for henceforth Russia must maintain in the Pacific a squadron superior to the entire Japanese fleets.

Whether the additional vessels are furnished by Russia alone or by Russia and her allies together, the result is the same, they are so many vessels diverted from Europe, wholly lost to the possibility of action in European waters, where the great engagements are to take place.

The Chinese and Japanese fleets, now combined under the Japanese flag, will retain in the Pacific all the Russian and French vessels sent as reinforcements during the war; and during the accomplishment of the extensive programme of construction entered on by Japan, as each new vessel hoists the Japanese flag, an equivalent must weigh anchor from Cronstadt, Brest or Toulon and bid farewell to Europe.

This loss has cut down seriously the possible preponderance of the available fleets of the Dual Alliance over those of Great Britain, and after a few years, when the English and Japanese harvests, now sown, are reaped, it will be practically impossible for the fleets of the Dual Alliance in Europe to maintain an equality with those of Great Britain.

The war has thus produced an effect equivalent to the addition of a new fleet to the British fleets, and the addition of a new nation with vast and willing resources to the British nation in the effort to create and maintain a naval superiority over the Dual Alliance.

As a consolation for the universal regret felt when European influence caused Japan to recede from her conquests only to clear the way for Russia, it should be borne in mind that the renunciation of continental territory and restriction to water-locked possessions will throw Japan's aspirations more toward naval affairs. The foundations are laid for a great naval power, which will be the greater for not having continental possessions to divide the national mind and national treasury. In consequence, the bulk of the war indemnity and of the price paid for the renunciation of territory, and the bulk of future appropriations, will flow to the creation of a new navy, as did the war indemnity from France to the creation of a new German army.

This result is far more advantageous to Europe. It is better for the present that Japan's resources should flow to naval power to call away Russian vessels than that they should flow to military power to divert Russian troops from Europe.

Those who were inclined to criticise the British non-interference in behalf of Japan will come to recognize that no break has been made in the wise counsel that has steadily guided British foreign policy.

Thus, in sum, the war in the East, the rise of Japan, has come at an opportune time to enter a lever under the scales of political Europe, to sustain them from toppling under the weight of the great aggressive alliance.

In order to enter with a preponderance of strength into the struggle for the first great object of their ambition, the overthrow of the British empire, France and Russia must now look to the result of their overtures to Italy, whose bond with the Triple Alliance will soon be loosed. If Great Britain, through the peculiar, substantial inducements that she could make with her wealth and her fleets, can secure and guarantee Italy's neutrality, or, if she enters an alliance with her, Europe will be guaranteed against Russian victory, and, as will be seen below, since Russia has more interest in waiting than in engaging in uncertain war, a new guarantee of peace would be given and impatient France would be doomed to longer waiting.

The creation of a naval power in the East, dedicated to enmity to Russia, has come to the rescue of Europe. The rise of Japan as a rival and aspiring power will call a larger share of Russian attention to Asia, where lies the great field of her legitimate ambition.

Russia has been held up to the gaze of the world, and the chances are somewhat better that all the nations may come to realize that she is the universal enemy. Such a realization might throw Russia into Asia, save Europe, and set our planet right again, leaving the great struggle of the races to be fought under fair conditions, which would end in the elevation or else in the extermination of the lower.

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The criticisms in the interesting and valuable discussions above are of two kinds: technical, relating to the estimates of naval strength; and general, relating to what may be termed the Russian question. The first takes issue with the method employed for determining naval strength, and challenges the results; the second doubts the existence of a Slavic wave, or doubts the seriousness of the question, or sees the possibility of the growth of new modifying factors. Other criticisms are parts of or attach themselves to these.

A navy or a fleet, being made up, being the resultant of the combination of a number of vessels, any process that deals with the qualities of a fleet or navy must be a numerical process. The strength of a fleet or navy is derived from the strengths of the individual vessels. Though the strength attributable to any vessel will vary with the combination of vessels, the strength of the combination is essentially distributed among the individual vessels, a loss of any one of which must entail a certain loss to the combination. The strength of a fleet or navy being thus essentially the aggregate of the quotas of strength of the individual vessels, any process or method for determining the strength of a fleet or navy must be essentially arithmetical.

The value of any element for prosecuting war lies in its capacity for inflicting injury. The measure of the value of a fleet or navy is its power to inflict injury. The power to inflict injury will depend on what may be termed the innate power of the agent and on the opportunity for the exercise or use of this power. This opportunity depends on the strategic conditions or circumstances resulting from three kinds of elements, from what may be termed the innate strategic elements, depending upon the relative innate powers, from what may be termed the natural strategic elements imposed by the necessary positions of advantage or disadvantage, and from what may be termed the human strategic elements. The human elements of strategy can never be determined beforehand, and even where previous experience or record gives grounds for presumptions, these should not enter into estimates similar to those proposed. The natural elements of strategy will have a profound influence in determining the results of the possible and probable sea struggles of the nations of Europe, and should be separately and specially considered in drawing ultimate conclusions. For the purposes of the paper and for the present purpose, the natural and human elements of strategy are eliminated by the assumption of equality, so that, whether it is a question of individual vessels, of fleets, or of navies, the second factor for determining the value or strength, the opportunity to use innate power, is assumed to depend only on innate powers themselves. Thus restricted, the problem of the estimation of naval strength resolves itself into two parts, the evaluation of innate power, and the opportunity of advantage or occasion of disadvantage resulting from the relative powers in the case in question.

The innate power of a vessel is composed of two elements, the power of her weapons, and her ability or power to use them. Moreover, these two elements enter as factors; either of them would be useless without the other. The final exponents of the two, however, are not the same, for the element of offense, in its silencing effect on the weapons of the enemy, enters as a part of the element of defense, and its final exponent will in consequence be greater.

Let a rapid mental process make a rough evaluation of the two elements or factors, offensive power and defensive power, for a typical vessel of each of the recent types, assuming, as this does, that the vessels are within their radii of action; let the factors be held up apart, though with the multiplication sign between them, with unity as the exponent of each factor, if the imagination finds it difficult to picture an exponent greater than unity for offensive power, and let the products stand opposite. Examine the column of products. Passing down from the battleship to the coast-defense the difference is moderate, but from the coast-defense vessel to the armored cruiser the difference is enormous; the armored cruiser and the very large protected cruiser peculiar to the British navy do not differ largely, but between them and the ordinary cruiser there is another enormous gap; passing down through the cruisers to the gunboats and torpedo vessels and torpedo boats, the difference continues more or less regularly.

What do the two gaps in the column indicate? They indicate that the vessels on different sides are so different in power or force that a necessary assumption of equality in the human element of strategy will forbid them engaging each other, except where the conditions are such as to force the weaker. Moreover, this gap cannot be spanned by superior numbers. A vessel on the higher side engaging any number on the lower will always possess that strategic advantage of inflicting more injury than she suffers.

If the columns are divided by the tonnage of the vessels in each case, these gaps will be found to be even wider. There will be this difference, however, the very large British protected cruiser will pass over to the lower side of the gap. It is only by virtue of her great size that she can enter the list of the French armored cruisers of less than half her tonnage. If tonnage is the basis, she must go over to the ordinary cruiser side or else enter the other side with a heavy coefficient of reduction. Another noticeable fact is that now the armored gunboat rises up out of its rank and can be admitted even across the lower gap.

Take now the types of vessels of previous decades. The battleships and coast-defense vessels produce products that lie between the two gaps. The cruisers all drop well down below the lower gap.

Thus for all types of vessels, strategy has put up two essential barriers that classification for estimates cannot cross, one that shuts off unarmored tonnage, and one that divides armored tonnage into two parts. When control of the sea is the object of naval engagements, and where both sides possess considerable quantities above the upper gap, the rôle of the vessels below the lower gap must be considered as only auxiliary. These being the conditions of the coming engagements, it may be assumed, as stated in the paper, that unarmored vessels will not enter as deciding factors. Further, the upper strategic gap across the middle of armored tonnage indicates that vessels on the lower or inferior side will not engage voluntarily those on the upper side. It indicates that the first engagements will be between vessels on the upper side, and the subsequent engagements between vessels on the lower side and what vessels on the upper side as may have survived the first engagements.

Thus the classification used in the paper, which eliminates unarmored vessels and then divides armored vessels into standard and inferior armored vessels, according to fitness to figure in the first series of engagements or only in the subsequent series, this classification which in the discussion is spoken of as "faulty," is the one made by essential strategy, the only rational classification possible which can give an idea of what forces can be thrown into the successive engagements or what the actual naval strength of a nation is.

The classification being made, the next step in the determination of naval strength consists in the estimation of the power or force which the nation in question possesses in each of the three divisions, using these three kinds of power in making all comparisons and drawing all conclusions. In making such an estimate, the only plausible basis is that of tonnage, affected by a coefficient or factor of efficiency, furnishing the two factors quantity and quality. Any descriptive method whatsoever will be found laborious, lacking in comprehensiveness of application, and altogether inadequate. All the features of a vessel may be classified as elements of offense or elements of defense. Any one or any number of one or the other or both of these kinds of elements taken as a basis will be found utterly inadmissible on the slightest examination. The features of vessels classed together are too varied to admit of any descriptive method whatsoever. The varying features cited in the discussion criticising the method of using tonnage show that the method of tonnage is the only plausible method. Since it was necessary to estimate the naval strengths, it may be interesting to know what other method may have been in the mind or could have been suggested by the author of the discussion in question.

The tonnage furnishing directly the factor of quantity, it remains to determine the factors of quality. There are two methods, which may be called the exact method and the approximate method. The exact method consists in the following parts: (1) The determination of the elements of offense and the elements of defense and the relative weight or value of each element and the nature of its relation to the whole. (2) The establishment of a standard in each division of the classification for each of the elements of offense and defense. (3) The determination for each vessel of sub-partial coefficients representing the degree or value of its various elements of offense and of its various elements of defense as compared with the standard elements. (4) To derive partial coefficients, one a coefficient of offense, and the other a coefficient of defense, by treating the sub-partial coefficients of offense and those of defense found in (3) by the values or weights found in (1) in accordance with their relation to the whole. (5) To derive the *coefficient of reduction* for the vessel by taking the simple product of the two partial coefficients, the coefficient of offense and the coefficient of defense. This coefficient of reduction will represent the *quality*;

the *equivalent tonnage*, the quantity sought, will be the product of the actual tonnage by the coefficient of reduction. The sum of the equivalent tonnage for all the vessels of the nation in the division will represent the naval strength of the nation in that division. The divisions of the classification represent adaptability for the various kinds of engagements, and the results arrived at furnish all the elements needed for a comparison.

Moreover, a coefficient of reduction can be established for passing from one division to another, and the strength of the entire navy can be expressed in a single quantity in any of the divisions, expressing the nation's entire force available for any kind of engagements, engagements against unarmored tonnage, against inferior armored tonnage, or against standard armored tonnage. It could further be used to transfer one or more vessels from one division to the other, and would show the result or advantage of detailing it or them to perform one or the other duty. It would give an insight into the advantage of different combinations of vessels in a fleet, of the value under various conditions of a fleet of heterogeneous vessels, of the advisability of having any vessel or number of vessels detached or withdrawn in any engagement or during any portion of an engagement. Further applications need not be pointed out; they will be contained in a subsequent paper devoted to the exact or absolute method outlined.

In the approximate method the analysis of the features of the vessels is avoided by assuming that these features, reflecting the condition of progress of the time when they were produced, will have their general quality defined by this condition, and the method consists in finding the mean date of the tonnage of each division. In comparisons this method requires that cognizance should be taken of the relative degree of progress in each country at the time of the mean date, and of the degree of improvement which the interval between dates at the time would indicate. To make the results more accurate, general cognizance can be taken of the prominent features of design or construction influencing quality, which differ in the countries compared. For the purposes of the paper, it was sufficiently accurate to eliminate unarmored tonnage as not influencing primarily the result of the engagements for control of the sea, and to draw the line between standard and unarmored tonnage by judgment between the vessels considered fit and unfit to enter the first series of engagements. In placing this line, the vessels on both sides were analyzed summarily as to their elements of offense and defense and the decision made accordingly. Though to indicate in a few words the general character of the limiting vessels, reference was made to their date, it was not this date that determined the decision. It is not *age*, as erroneously concluded in the discussion, but *fitness* that determines whether by this method a vessel should be entered on one side or on the other of the dividing line. An armored cruiser just launched cannot enter the class of standard armored tonnage, though a battleship launched ten years ago can. *Age* is used in arriving at rough conclusions as to quality, but has no influence, except in so far as it influences fitness, in determining the class or division to which a vessel is assigned. In the first method, the principle of which is precisely the same, no use whatever is made of age.

It should be pointed out that in this approximate method the age of a vessel does virtually act as a coefficient of reduction, and that in fact every ton of every ship does not receive equal weight, as supposed in the discussion, for the age of each vessel, assumed to be an index of its quality, has its due proportional influence in determining the age of the whole, which is taken as the index of the quality of the whole.

As to the choice of the date to be assigned as the date of birth of a vessel from which to reckon her age, it should be borne in mind that the object sought is quality, and that the age should transport the mind to the date whose degree of progress is reflected or embodied in the vessel. Though the design of a vessel may not be changed during the course of her construction, though weights and dimensions may remain unaltered, the quality of the material, a quality ranking next to design in importance, changes during practically the whole course of construction. This is particularly important in the case of armor. Radical changes may have taken place in the quality of armor turned out when the vessel is laid down and the quality turned out when the armor is put on.

In consequence, of the three dates in the growth of a vessel, the date of laying down, the date of launch, and the date of completion, the middle date, the one employed in the paper, and not the first date, as advanced in the discussion, is the date whose degree of progress is more nearly embodied in the vessel, and which in consequence should be selected as the index of quality.

In the case of the two fleets, British and French, it should be pointed out that in England few changes, if any, are made in design, even in details, during the course of construction, which is rapid, while in France changes of a serious character are constantly made, such, for instance, as the moving of the torpedo tubes from above to positions below the water line, or even in the distribution of armor, modifications of the splinter deck, changes that have been recently made in consequence of the development of the rapid-fire gun and the use of high explosives for bursting charges, and the use of steel shell containing large charges of powder. Thus in France, where the construction is long, due in part to the changes referred to, changes which add to quality, an advantage which has been accepted to counterbalance in part the disadvantage of delay, the real date of a vessel is much farther from the date of laying down than in England; and, further, for the same reason, to use the date of launch for determining the age of a vessel in both cases is a discrimination to the disadvantage of France instead of a discrimination to the disadvantage of Great Britain, as advanced in the discussion.

It should be pointed out, also, that in the case of the British vessels of large tonnage it will be found on examination by a rough application of the exact method that the powers of offense and of defense are not as commensurate with their tonnage as they are in the case with contemporary French vessels. A greater quantity of coal adds but little to increase military superiority when the enemy has all the coal needed. It will be found on analysis that the battleships of the Royal Sovereign class outmatch very little for offense and defense the contemporary French battleships of more than two thousand tons less displacement, and, in consequence, the simple addition of tonnage is a discrimination to the disadvantage of France instead of the disadvantage of Great Britain, as advanced in the discussion.

It is not the author's intention to raise the question of the comparative value or worth of French and English construction, but the question of discrimination being up, he considers that in addition to the discriminations pointed out as disadvantageous to France, there is another of not less importance in the assumption that design in the two countries has been on an equality of advancement or progress. Not to mention such points as the perfection and adoption of water tubulous boilers, many years old in France but comparatively new in England, it will suffice to point out simply the lapse of several years that has intervened between the time of appreciation in the designs of the two countries of the necessity of the distribution of armor with a view to protection against projectiles carrying high explosives, and semi-armor-piercing shell with heavy powder charges, differences as indicated in France in the increase of area covered by light side armor, in the protection of medium caliber guns and the development of the splinter deck.

Thus, in sum, the method and classification employed in the paper for the estimation of naval strength, criticised in the discussion, are founded on and flow out of essential innate strategy. Though all of the intermediate elements that must necessarily be incident to an estimation of such a nature as that of naval strength are free and open to individual opinion or judgment, though the parts and details may vary, the author believes the method to be final, and combined with a separate consideration of natural strategy and mental estimate of human strategy, to be comprehensive and unassailable.

In the case of the approximate method, used for the purposes of the paper, the result instead of discriminating against Great Britain, as advanced in the discussion, discriminates incidentally against France.

For the comparison of the future naval forces, it will suffice to mention that the new vessels causing the changes are all enumerated, and that the dates set for their completion were derived a year ago in each case by conservative estimates based on the stages of advancement and taking due account of the time required for building in the different countries. If these times have changed or do change, they will modify only to that extent the result.

It should be borne in mind that in England, where of recent years rapidity of construction has taken the form of strong rivalry between the different yards, the terms date of laying down, date of completion do not mean what they do in France. For instance, in England at the date of laying down material, progress has been made in the preparation of material, which would correspond to a date some time later in France. In the case of the Magnificent and Majestic, put down as expecting to be completed before the Renown, in July, 1896, if these vessels are actually to be ready for commission at that date, a prodigy will have been performed even for England's remarkable rapidity of construction, and no adequate cause can be assigned other than an intense desire of the authorities to remedy to the utmost the inevitable condition pointed out in the paper.

Referring to the accuracy of numerical statements in the paper, occasion should be taken, in view of the equivocal use of the word "exaggeration" in a subsequent discussion, to mention at this point that they are from sources of the utmost reliability. The figures for strength of armies are from the Bureau of Information of the War Department, corrected by the Bureau up to the date of completion of the paper. The figures for naval expenditures and appropriations are from official returns in the budgets of the different countries. Those for populations and rates of increase are from statistical returns made in 1894. Those for vessels, tonnage, date of launch, material of hull, kind of guns, etc., do not admit question. The only possibility for variation from the statements lies, as pointed out, in the estimation of dates of completion of vessels now building, dates liable to be changed, and even here modifications can be but slight, and, where found, will be the results of abnormal conditions which cannot enter estimates.

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History presents two forms of sociological wave. In one form, a race or nation or a religious sect has advanced across territory not its own in one or more pronounced directions. Such has been the case of the invasion of Europe by the Huns, the Saracens, the Mongols, and the Turks. In the other, a race or nation has expanded circumferentially like a wave of disturbance, as in the case of the Celts, Romans, and the Teutons in Europe and the Mongols in Asia. The former form of wave, which may be termed the *wave of translation*, has had its sources in sociological impulses beyond Europe. The waves have advanced across long distances in comparatively short times, receiving but slight reinforcements and expending their force till checked by sociological barriers, when they began to recede. The invaders have been of different race origin and have remained alienated from the native peoples, and recession, though slow, has been steady and sure.

The second form of wave, which may be termed the *wave of radial expansion*, has had its historic origin in each case in Europe itself. The sociological forces have been long and cumulative in their processes, the waves gathering new force as they advanced along radii or, as in the case of Rome, around the whole circumference. The races have all been of Aryan origin and have spread over Aryan expanses. They have been mixed with the native peoples, have assimilated them, have been assimilated by them, and their influence has been profound and perpetual, exception being made of Rome in her outer circles, which reached far into the regions of the lower races.

It is to the second form of wave that the Slavic wave belongs. Starting from a nucleus in the central part of what is now European Russia, with an area of about 800,000 sq. miles, after the overthrow of the Tartars four centuries ago, it has extended radially in all directions by steady, unremitting strides, till it now compasses more than 8,500,000 sq. miles, about ⅙ of the entire land surface of the globe. This unprecedented expansion belittles Rome when she spread by successive steps in about the same length of time over Italy, then Carthage, Greece, and Macedonia, then Spain and Cisalpine Gaul, then Syria, Parthia, Egypt, and Transalpine Gaul. It overshadows the remarkable phenomenon of the Teutons setting forth from the German forests, tribe after tribe, Goths, Franks, Burgundians, Vandals, Angles, Saxons, Jutes, over one Roman province, then another, into Italy, over one part of Gaul, then another, into Spain, over to Africa, and across to Britain. The Romans assimilated the tribes of Itâly, and later mixed with the inhabitants of Gaul and Spain, and everywhere exerted a profound influence; but in their outer dominions their rule was only military, the rulers remaining foreign to the ruled; the fatal characteristic of the wave of translation, foredestined to overthrow.

The Teutons went forth as separate tribes, and mixed with but did not assimilate the native tribes overrun. Their influence was everywhere profound, an exception being made of the Vandals; but it gave rise to new composite nations, the invaders gradually losing themselves in the new nations.

The Slavic expansion has been characterized by universal assimilation. Whether Slavic influence pre-existed or not, the moment the Russian frontier has swept around a section or country, an irresistible system of Russifying has set in. It is as though the Romans had assimilated the populations beyond Italy as well as those within Italy; as though the Teutons had been united instead of appearing in different tribes, and had assimilated as they advanced. The Slavic wave, advancing with an unbroken front, without any tendency to internal division, absorbing into itself new populations, grows stronger and more irresistible instead of dividing, weakening, or diluting its force, as did the Roman and Teutonic waves. Vast, wild expanses, that would have frightened back or swamped a less rugged race, have been leaped till already the northern and eastern boundaries are oceans of two continents. Sociological barriers have been as naught. An ostrich-like digestion has assimilated foreign sociological morsels hitherto utterly indigestible. No wave in history has had the proportions of the Slavic wave, and none offers even the suggestion of a parallel of the combination of elements that make up invincibility, irresistibility. Attention may be called at this point to the fact that no radius has been excepted in the advance along the whole circumference.

Referring to the discussion that advances the idea of specific, not general, expansion, it will suffice to point out that, taking a map and turning back only a few pages in history, starting in Finland at the Swedish boundary, continuing down through Europe, over to Asia, and across the sea to Corea, it will be found that every foot of Russia's endless frontier is under heavy tension, is pressing heavily outward. It may be added, also, that the simple reference made to Turkey, India, and Corea, in connection with the idea of specific expansion, is sufficient to show that the expansion is general.

Of the remarkable features of this wonderful sociological phenomenon, the most striking is the manner in which the Non-Aryan or Turanian races, as well as the Aryan races, one and all, are being assimilated. Though other and higher Aryan races may bear sway in Asia, no one gives promise of being able to assimilate the Asiatics. The rugged Slavic race alone gives promise of being equal to this giant's task of Aryanizing Asia.

Though the process of Russianizing or Slavonicizing elevates the lower races, and would infuse a wonderful new life into the stagnant blood of Asia, it drags down mercilessly the higher races; it would throw Europe back almost to the days of serfdom, with long, agonizing, but relentless pangs. The Russianization of Poland is a case of the process of this assimilation, though with the other nations, not having the preparations of similarity, of proclivities and temperament, the process would be far more severe. Though the sword, referred to in the discussion, would characterize only the first conquest and the suppression of subsequent rebellions, the ordeal involved in the extinction of native tongue, the destruction of individual liberty, of individuality itself, would be far more severe than "fire and sword." To show that, viewed from the westward, a dense darkness hovers over the Slavic wave, it need only be recalled that the mass of the Russian nation, the mass that makes up the wave and gives it the characteristics pointed out above, was only emancipated from serfdom in our own generation, and on the ladder of civilization in its great objective feature, higher standard of comfort and amelioration of the condition of individual life, stands on a round far down, centuries below the round occupied by western Europe.

Russia's representatives abroad, all of whom come from among the aristocracy, a class largely of Teutonic race origin, having had centuries of cosmopolitan association with western Europe, one of the most intelligent, highly educated classes in the world, produce false impressions as to the Russian race. Though they formulate the nation's ambitions, though they wield the great masses with unsurpassed sagacity, having the power to tax to any limit the resources offered by the countless number of stalwart men, seizing on all the improvements in weapons and in methods that western science devises, though peerless in diplomacy, though contributing the guidance of a high intelligence, and though to the greatest advantage wielding the great race with the incalculable power given by absolute obedience, innate courage, and unlimited powers of rugged endurance, they nevertheless form but one and one-half per cent. of the population. The process of assimilation, of transformation, wherever found, has always and must always come from the masses who stand immeasurably below.

Russian ambition, though true to the universality of its possibilities and neglecting no opportunity in Asia, is centered hard on Europe, where it takes the immediate definite form of seeking a southern waterway to the westward, having already a northern one, and gaining at the same time the gateway to the three converging continents. The strategic importance of the Balkans, recognized all down the centuries, cannot be overestimated. Its possession by a strong nation would have a profound, far-reaching effect on the Russian question, as pointed out in the discussion; but, on the other hand, its possession by Russia would be a death-knell to western Europe. Of such vital importance is this Balkan question that it may be assumed that Russia will not be allowed by the nations awakened to antagonism to occupy it without war, while it may be assumed with equal certainty that Russia will not peaceably allow it to be occupied by another strong nation. A strong Balkan nation can arise only by a new birth. It is out of the question that Austro-Hungaria, the only nation available, finding great and growing difficulty in containing the heterogeneous elements in its present borders, and having no expanding population, will attempt to occupy or could effectually occupy the peninsula.

What are the chances of the birth of a new nation? What are those signs in Southeastern Europe which in the discussion are taken to be signs of pregnancy?

The most marked sociological and political feature of contemporary history, referred to in the paper, is the tendency to consolidation in peoples of the same race and the tendency to separation in peoples of different race, though under the same government.

The total population of the Balkan peninsula, including the Hungarian provinces of Bosnia and Herzegovina, is about 20,000,000, exclusive of the Turks, who number about 1,700,000, whose occupancy is not permanent. Of this population about 5,000,000 are Roumanians of mixed origin, about 3,300,000 are Bulgarians or Bulgars of Turanian origin, with Slavic admixture; about 2,000,000 are pure Slaves, and the remainder, 10,000,000, are made up of Greeks, Albanians, Armenians, Magyars, Circassians, Jews, and Gypsies. This heterogeneous population has shown no tendency to unite. The "signs" have been those of consolidation of the races emerging from the Turkish yoke, and of formation into separate small states or principalities. Growing antagonism and rivalry, not tendency to union, have been the characteristics of these small states in their relations with each other. Even the power of self-government is questionable, so deep have been the effects of the centuries of subjugation to the Turk. Of these contiguous races, no one has shown yet any particular capacity for assimilation. The Magyars of Hungary have shown themselves equally incapable. Though the influence of the western powers might effect a Balkan Confederation in the face of Russia, or Russia and France (the power to do which in the latter case will not be here discussed), yet all the indications point to the continued separation of the races. As far as can be seen now, these races will not flow together until they are all absorbed in their great assimilating neighbor. This destiny seems set apart by fate for all the small heterogeneous races found in Bohemia, Hungary, and Southeastern Europe, which are fast ripening under Russian influence, and for the rest of the races of Europe also, unless some unseen unifying process comes from below the horizon.

Occasion should be taken to point out here that sociological processes, particularly those embodying increase of population and assimilation, are slow, like all great, irresistible forces. It is, in consequence, beyond human knowledge to fix times for the accomplishment of the great phenomena foreshadowed above. It may be added that it is a superficial reading that classes the paper in the category of date-fixing prophecies. More careful reading will show that the paper is an analysis of situations, certain, probable and possible, only in so far as they permit analysis, and that it attempts in no manner to determine the other indeterminable elements that enter to decide the times of the war.

As to the peninsula at the other end of Europe, that appeals so strongly to the strategist's eye, whose possession as the home of a great and powerful race would profoundly influence the destiny of Europe, it needs only to be called to mind that all indications point to continued decline in Spain, internal division, increased indebtedness and loss of credit, rebellion in colonies. Rejuvenation has not occurred in the history of Latin races grown rigid with age, and there is no nation in Europe, excepting the one in the East, that could spare population to infuse new blood into the Spaniard's veins. It may be added, further, that it could not be assumed that a new Spain would be with the passive powers. The immediate advantages of spectatorship or alliance with France and Russia would be even greater than those pointed out for Italy. Unless Spain, which is farthest from Russia, could be taught to see across immediate interests to see the final vision, it would be a dangerous experiment, if it were possible to make it, to put great power into her hands.

The picture of a great Iberian power, more even than the picture of a great and growing Balkan power, being allowed to rise from infancy to block the path of Giant Russia, a picture outlined from broad mental sweep and strategic grasp, is but a vision that vanishes under a steady gaze.

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The conclusions arrived at are, in sum, as follows:

1. The rise of Japan exerts a stabilizing influence on Europe in restoring equilibrium on the sea, and this equilibrium promises to continue till Italy decides on her future policy, when the treaty of the Triple Alliance expires. It further raises a serious obstacle to Russian advance in the East, and will draw away from Europe a larger share

of Russian strength, diverting more of Russia's attention to Asia, where lies her great mission. The events of the war in the East, particularly those connected with its conclusion, have drawn the gaze of the world to Russia, from which fruitful results will flow. These events have emphasized, in addition, two facts that should be signalized, namely, first, the solidity of Russia's alliance with France, a fact emphasized by every event of the past few years, an alliance which, as pointed out in the paper, can be dissolved only by disastrous war, threatened or inflicted, or by the game of waiting, a game advantageous to Russia, which might overtax French patience, or, if possible, might cause a change of sentiment in France; second, the ascendancy of Russian diplomacy, the consummate ability of its diplomats, and the tremendous vantage-ground that it holds while Western Europe is divided.

2. The naval estimates, questioned in the discussion, are based for method and classification on essential strategy, and in results are accurate within the degree of approximation suited to the present treatment, admitting of variations as pointed out, which are discriminations against France in the estimates of vessels completed, and from appearances against England in the estimates for the future in the slight deviation from the normal length of time that may be consumed in the completion of vessels under construction.

3. The situation in Europe, viewed in the light of history, presents the most remarkable phenomenon of sociological wave that the world has seen, a wave which, though still in its youth, has reached proportions hitherto unknown. Belonging to the irresistible class of radial expansion, this wave embodies all the elements of irresistibility found in previous examples, without any of the elements of weakness. Physical and sociological obstacles hitherto insurmountable vanish as nought. This wonderful phenomenon offers the grand prospect of Aryanizing Asia; but, on the other hand, it is a terrible menace to Europe, which would be thrown down centuries of progress; while the situation in Europe, before this menace, is nothing short of desperate.

The absorption of Southeastern and large additional portions of Central Europe appears inevitable. Whether Western Europe is to follow will depend on the capacity of the western nations for union.

The test of history is to be applied to our high western civilization, whether, with its ameliorated condition and higher life of the individual, it has lost, like the high civilizations of the past, the hardihood and elements of combination or association, which alone can guarantee existence in the face of a lower but more rugged race which uses all the weapons and all the methods of the higher race, while possessing greater endurance, if not greater courage, where the individual is lost in the unity of the whole.

PROFESSIONAL NOTES.

THE BRITISH NAVAL MANŒUVRES FOR 1894.

[ENGINEERING.]

The official account of the partial mobilization and naval manœuvres of last year has just been issued. It is a brief document, dealing in a summary method with the operations of the two fleets. It appears that 96 vessels of all classes were engaged, 24 of these being torpedo-boats and 26 small special service vessels. There were 33 cruisers, 12 battleships and one coast-defense vessel. The total was larger than any during the past five years. The total tonnage was 305,362, the number of officers and men employed being 20,853 of the Royal Navy; in addition to which there were 535 men of the Royal Naval Reserve mobilized. The whole number of ships were divided, as usual, into two bodies, designated the Red and Blue fleets.

It is unnecessary to follow the bare description given of the details of operations. The operations took place mostly off the coast of Ireland. There was a forbidden belt. There was the usual amount of scouting, cruising and manœuvring, and on August 5 the combined Blue Fleet, composed of 22 ships, were sighted on the port bow of the B Red Fleet, consisting of 15 ships. The Blues manœuvred to prevent the Reds from getting into Belfast, and an engagement which lasted about 50 minutes took place. The Red ships got into Belfast Lough, but in doing so they passed within six cables of the Maidens, and thus broke one of the rules, the penalty being that they were put out of action by the umpire for 24 hours. After this the Blue Fleet stood to the southward to look for the remainder of the Red Fleet, which was discovered. An engagement began, and the part of the Red Fleet which had been ruled out of action followed and took part in the fight. As, however, the Red ships out of action should not have been present, the victory was therefore given to the Blues, who were outnumbered to the required extent. This must have been an unpleasant surprise to the Admiral of the conquered fleet, who was not aware that his auxiliaries were officially non-existent, although very palpably present in actual force.

No ship was put out of action by a torpedo-boat, a fact to be chiefly attributed to the lightness of the nights. One of the Red torpedo-boats, however, had apparently a chance which she failed to take advantage of, supposing her enemy to be one of the group exempted from torpedo attack by the rules. This incident, as well as that of the Red ships being out of action, and yet able to take part in the fight, shows the difficulty of bringing make-believe warfare to the likeness of the real thing.

The Red torpedo-boat referred to, which failed to attack her opponent through a misconception of her character, had been driven off by a "catcher"—we thought the term was tabooed in naval circles—and at first missed the Blue Fleet, but managed to keep up with it and got within range of the rear ship, which, as stated, she did not attack. The lieutenant in command states that, owing to the speed of the hostile fleet, the boats were unable to regain their position for attack when once it had been lost. "From this it seems permissible to infer," says the report, "that high speed will be of itself no unimportant protection to ships traversing at night narrow waters infested by torpedo-boats"; a proposition which we should have thought a self-evident fact.

The torpedo-boat operations are described as having been upon a too restricted scale to supply much valuable instruction, a remark which applies equally as well to the report itself. So far as the operations went, however, they tend to confirm the view that the most effective employment of the torpedo-boat in war will be limited to sending her to attack an enemy's ship in a known position within the boat's range of action. The necessity of combining with torpedo-boats vessels of a larger class to discover the enemy is also insisted upon. A mere flotilla of torpedo-boats is therefore considered "as a belligerent factor of distinctly imperfect efficiency." It is surprising how much attention the torpedo-boats always seem to occupy in these manœuvres, and yet we are always being told they are little or no good.

TEST OF THE PNEUMATIC GUNS.

[American Engineer and Railroad Journal.]

In our issue for September, 1894, we illustrated and described the pneumatic dynamite guns that have been placed at Sandy Hook for the protection of the channels entering New York harbor. Our readers will remember that this battery consists of one 8-in. and two 15-in. guns, built by the Pneumatic Torpedo and Construction Company. For the details of the arrangement and construction of the battery we refer to our previous article.

As the guns were built under a contract with the government, wherein the latter assumed no responsibility except to pay for the guns, provided they fulfilled the requirements of the agreement, it was of the utmost importance that the performance of the guns should be such that the most exacting board could find nothing to criticise. The testing of these guns had been carried on for some time under the auspices of the company's officers, and an elaborate system of records preserved showing the fall in pressure in the air cylinders for various air and service charges, the former corresponding to blank cartridges in the ordinary rifle. After a long series of such trials, in which the setting of the valve was carefully observed for ranges and action, the official acceptance test was made.

The endurance test of the whole plant was, as given in our previous account, 50 rounds in the first hour, 20 being from the 8-in. gun and 15 from each of the two 15-in.; then, for the next two hours, 30 rounds per hour. These were merely "air shots," but the valve was set for extreme range. The results of this excessive trial, that far exceeded anything the battery could ever be called upon to meet in service, were that 50 shots were fired in the first hour, 33 in the second and 36 in the third. The initial air pressure at the firing of the first shot was 1008 lbs. per square inch, and though this was not exceeded at any time during the trial, it was touched at several times during the second and third hours. The lowest point touched by the pressure was 930 lbs., at which the sixth shot in the third hour was fired. It may be roughly stated that a firing pressure of 1000 lbs. was maintained throughout, and no shot, with the single exception of the one mentioned, was fired at less than 990 lbs.

We have mentioned this endurance test first because it depended upon the machinery of the steam plant for its execution, although it was the last on the list.

The development of the pneumatic gun—for it has been a case of development—started with the fundamental idea of throwing a charge of dynamite with compressed air; and it having been demonstrated that this could be done, it became necessary to so control the admission of the air that the shot could be fired accurately, for it would be of little use in hurling dynamite about unless there is some probability of its striking the object at which it is aimed, and at this point the development of the gun came in as exemplified by the wonderful valve designed by Captain Rapieff.

It is useless to deny that the original guns were inaccurate, but this does not hold good of the present battery at Sandy Hook. Through the courtesy of the company we are enabled to give diagrams of the targets of three sets of these shots. The striking point of the shots was located by means of plane tables. For the shorter ranges there were two observers stationed on either side of the battery, at distances of 596 yds. to the right and 627 yds. to the left; while, for the longer ranges, there was a third observer on the Romer Shoals beacon, which stood off from the line of firing at an angle of 17° 19′ and a distance of 5150 yds.

It would be uninteresting to our readers to recapitulate the results obtained by each shot, and we therefore confine ourselves to the sets that are here plotted. In Fig. 4 it will be observed that there is a plotting of the zones of danger to a first-class armored vessel due to the explosion of 500 lbs., 200 lbs. and 100 lbs. of high explosive respectively, as plotted from the formula of General Abbot. The plotting of the three sets of shots is done on this same scale.

Referring to Fig. 1, which represents the plotting of five shots fired from the 15-in. gun with 500 lbs. of explosive in each shot. The specification required that 74 per cent. of these shots should fall within the area of a rectangle 120 yds. long and 30 yds. wide. As a matter of fact, the whole five fell within a rectangle 41 yds. long and 10 yds. wide, while four out of the five fell on the line of fire. Fig. 2 is the similar plotting, eight shots containing 200 lbs. of explosive that fell within a rectangle 42 yds. long and 5 yds. wide, whereas the specifications only required that 54½ per cent. should fall within a rectangle 120 yds. long and 30 yds. wide. This Fig. 2 represents the extreme contract range, and the figures appended to the striking point of each shot indicate the distance from the battery at which it struck the water. Fig. 3 is a similar plotting of shots containing 100 lbs. of explosive fired from the 8-in. gun, and shows that the five shots fell within a rectangle of 57 yds. long and 3¾ yds. wide,* while the specification target was 120 yds. long and 30

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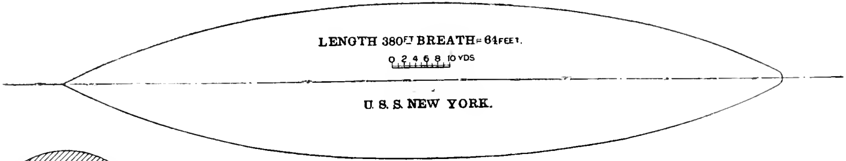
* In the drawing, the distance of shot No. 1 should be 2578 yds. instead of 2518 yds. as marked. The scale of the plotting is correct.



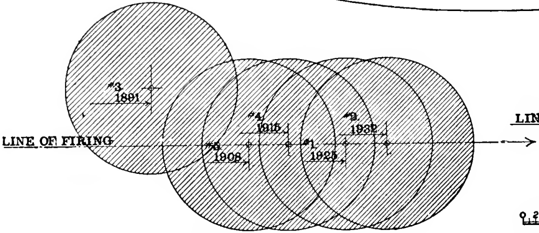


FIG. 1.

Plotting of Shots from 15-in. Gun with Full Caliber Projectiles and 500 lbs. of Explosive.

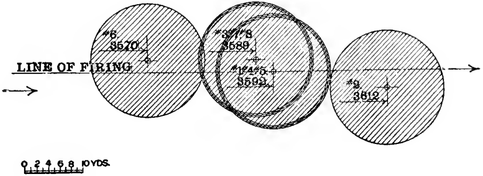


FIG. 2.

Plotting of Shots from 15-in. Gun with 10-in. Sub-Caliber Projectiles and 200 lbs. of Explosive.

PLOTTING OF SHOTS FROM PNEUMATIC DYNAMITE GUNS AT SANDY HOOK, N. J.

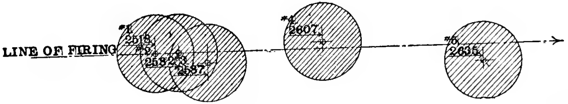


FIG. 3.

Plotting of Shots from 8-in. Pneumatic Dynamite Gun with 100 lbs. of Explosive.

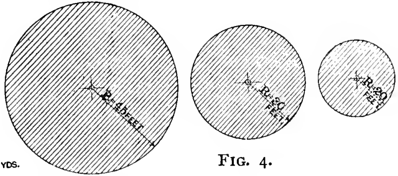


FIG. 4.

15-in. Full Caliber Projectile with 500 lbs. of High Explosive.

10-in. Sub-Caliber Projectile with 200 lbs. of High Explosive.

8-in. Projectile with 100 lbs. of High Explosive.

ZONES OF DANGER TO FIRST-CLASS ARMORED VESSEL, BY FORMULA OF GEN. ABBOT.]

yds. wide, with 66 per cent. hits required. We may therefore safely conclude that the accuracy of fire of these guns stands at a high point.

In our September issue we stated that these guns "command the whole southern approach to New York harbor." An actual plotting of the ranges shows that the 15-in. guns can throw 200-lb. charges to any point along the main channel for a distance of about 9000 yds., and for 4200 yds. through the swash channel. If a vessel were to enter the harbor at a speed of 20 miles per hour, it would, therefore, be exposed to the fire of the 15-in. guns with 200-lb. charges for 16 minutes if it were running the main channel and 7½ minutes if it were in the swash channel. In the first case the two guns could throw 20 projectiles, and in the latter 10 projectiles. Further, the guns are capable of throwing 500-lb. projectiles to any point for a distance of 4300 yds. along the main channel, and could fire eight projectiles at a vessel running 20 miles an hour before it was out of range, but could not reach the swash channel. This rate of firing cannot even be approached by the rifled guns, while there is nothing in the shape of a torpedo-thrower that can possibly be compared with this performance.

The acceptance tests also included an examination into the time required for the mechanical operation of the guns, such as elevating, depressing, and traversing. The guns can be operated by hand or by electric motors. The latter will carry them through 360° in 48⅞ seconds for the 15-in. guns, and 1 minute 25½ seconds for the 8-in. guns, while the same work can be done by hand in 8 minutes 11 seconds and 5 minutes 56 seconds respectively. The electric motor will elevate the 8-in. gun from 0° to 35° in 14 seconds and depress it in 15 seconds; the elevation and depression of the 15-in. gun to 34½° in 8⅕ seconds and 9½ seconds; hand power requiring 45 seconds and 48 seconds for the 8-in. and 26⅝ seconds and 26 seconds respectively.

One of the prime elements in the success of a dynamite gun is to have a suitable fuze. In regard to this we can only say at this time that out of all the shots fired—and there were 38 official and 8 extra for the company's exhibition—only two failed to explode on impact, and some were fired at the close range of 100 yds. In a future issue we will illustrate this fuze and then give a further account of its action in these tests.

The trials demonstrated that this battery has exceeded the demands of the specifications in almost every particular, and it has therefore been accepted by the government. The company are now at work upon the battery that is to be located in the harbor of San Francisco, thus giving to the main Atlantic and Pacific harbors of the United States the most efficient type of torpedo-throwing battery.

LEGAL ELECTRICAL UNITS IN THE UNITED STATES.

The units of electrical measure recommended by the International Electrical Congress, held at Chicago in 1893, were officially adopted by the U. S. Office of Standard Weights and Measures, with the approval of the Secretary of the Treasury. While this action affected all government contracts in which electrical measures were involved, it was in no way binding upon state, municipal or private operations. To remedy this deficiency, the law given below was passed by both houses of

Congress and signed by the President, and became a law on July 12, 1894. It supersedes all previous action in the matter, and substantially agrees with the recommendations of the International Congress. The specifications referred to in Section 2 have not yet been prepared by the National Academy of Sciences, but are expected shortly:

AN ACT TO DEFINE AND ESTABLISH THE UNITS OF ELECTRICAL MEASURE.

From and after the passage of this act the legal units of electric measure in the United States shall be as follows: (1) The unit of resistance shall be what is known as the international ohm, which is substantially equal to 1,000,000,000 units of resistance of the centimeter-gram-second system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grams in mass, of a constant cross-sectional area, and of the length of 106.3 cm.

(2) The unit of current shall be what is known as the international ampere, which is one-tenth of the unit of current of the centimeter-gram-second system of electro-magnetic units, and is the practical equivalent of the unvarying current, which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of 0.001118 gram per second.

(3) The unit of electromotive force shall be what is known as the international volt, which is the electromotive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of an international ampere, and is practically equivalent to $\frac{1000}{1434}$ of the electromotive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C., and prepared in the manner described in the standard specifications.

(4) The unit of quantity shall be what is known as the international coulomb, which is the quantity of electricity transferred by a current of one international ampere in one second.

(5) The unit of capacity shall be what is known as the international farad, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

(6) The unit of work shall be the joule, which is equal to ten million units of work in the centimeter-gram-second system, and which is practically equivalent to the energy expended in one second by an international ampere in an international ohm.

(7) The unit of power shall be the watt, which is equal to ten million units of power in the centimeter-gram-second system, and which is practically equivalent to the work done at the rate of one joule per second.

(8) The unit of induction shall be the henry, which is the induction in a circuit when the electromotive force induced in this circuit is one international volt while the inducing current varies at the rate of one ampere per second.

Sec. 2. That it shall be the duty of the National Academy of Sciences to prescribe and publish, as soon as possible after the passage of this act, such specifications of details as shall be necessary for the practical application of the definitions of the ampere and volt hereinbefore given, and such specifications shall be the standard specifications herein mentioned.

SHIPS OF WAR.*

[ENGLAND.]

THE MAGNIFICENT AND MAJESTIC.

The following comparative table gives the main features of the new battle-ships, compared with those of the Anson, the Royal Sovereign, and the French vessel Charlemagne now being built:

PARTICULARS.		MAJESTIC.	ROYAL SOVEREIGN	ANSON.	CHARLEMAGNE.
Length, feet		390	380	330	385
Beam, feet		75	75	68½	66 ft. 7 in.
Draught, feet		27½	27½	28	25 ft. 10 in.
Displacement, tons		15,000	14,260	10,650	11,232
Freeboard, feet		21½	19½	10¼	25 ft.
Indicated horse-power		12,000	13,000	11,000	14,000
Speed, knots		17.5	17 5	16.8	18
Coals, tons	at designed load	900	900	900	680
	total capacity	1850	1400	——	1100
Armament*	Main	4 50-ton guns	4 67-ton guns	4 67-ton guns	4 11¾-in. guns
	Auxiliary	12 6-in. Q.F. 16 12-pounder Q.F. 12 3-pounder Q.F.	10 6-in. Q. F. 16 6-pounder Q. F. 12 3-pounder Q. F.	6 6-in. B. L. 12 6-pounder Q. F. 10 2-pounder Q. F.	10 5½-in. Q. F. 6 4-in. Q. F. 36 smaller Q. F.
Total weight of armament and ammunition		1500 tons	1410 tons	1070 tons	Not known
Height of center line of heavy guns above water		27 ft.	23 ft.	19¾ ft.	29 ft.
Length of vertical armor		250 ft. (including citadel)	250 ft.	150 ft.	Entire length of ship
Weight of armor and armored deck		4300 tons	4550 tons	3130 tons	Not known
Weight of projectiles thrown in four minutes on either beam		30,000 lb.	27,000 lb.	20,000 lb.	20,000 lb.
Weight of projectiles thrown in four minutes axially, fore or aft		12,000 lb.	12,800 lb.	8000 lb.	14,600 lb.

* Exclusive of machine guns.

The Magnificent was successfully floated out of dock on December 19 and the Majestic on January 31. These two vessels form part of a fleet of seven of precisely similar character already under construction or laid down. When completed they will be, in point of weight of broadside and end-on fire, as well as in respect of armored protection, the most modern and formidable engines of war as yet seen afloat. For, although the main armament in the barbettes consists of 12-in. 50-ton guns, instead of the huge 70-ton weapons of the Royal Sovereign and Hood, the extra rapidity with which these lighter and more manageable pieces of ordnance can be worked, and the tremendous preponderance of large caliber quick-firers which can be discharged six and seven times per minute, render the weight of metal thrown in a given interval of time far greater in the two vessels now under consideration. Similarly, although the actual thickness of armor-plating upon the sides and barbettes has been lessened, its capacity for resistance has been increased

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* Details are from "The Engineer" and "Engineering."

fifty per cent. by Harveyizing it, and the extent of armored surface has been enormously developed. The superficial armored area of the Magnificent's great citadel is, independently of the barbettes, nearly 9000 ft.

The principal dimensions, etc., of the two new battle-ships are as follows: Length, between perpendiculars, 390 ft., or 415 ft. over all; beam, 75 ft. at the water-line; mean draught of water, 27½ ft.; displacement, 14,900 tons; indicated horse power, 12,000; speed, under natural draught, 16½ knots, under moderate forced draught 17½ knots; of coal capacity there is a total storage of 1800 tons, but only 900 tons of this can be carried at the designed draught.

The disposition of the armored protection is quite different from that of the Royal Sovereign class. Instead of a narrow strip of thick armor at the water-line, surmounted by another strip of very thin armor, the upper edge of which is 9½ ft. above the water-line, there is a broad streak of Harveyed steel 15½ ft. wide, stretching from apex to apex of a pointed citadel. This is 9 in. thick upon the broadsides and 14 in. thick around the barbettes, where it merges into bulkheads. Within this armored citadel is the thickest portion of the armored deck, where it is 3 in. on the flat and 4 in. upon the curved sloping edges. Forward and aft, beyond the armored bulkheads, the armored deck is 2½ in. thick at its stoutest part. But an important modification has been made in the armored deck. In all earlier battle-ships the outer edge of this deck is at the summit of the thick armor belt. In the Magnificent and Majestic, however, it curves downwards behind the vertical armor, and the lower edges of the two harmonize, as well as the outer edges of the forward and after armored decks, thus bringing the whole to a uniform level of about 5 ft. or 6 ft. below the water-line. The protective deck is, therefore, of a truly turtle-back character, as first of all developed so prominently in the design of the Vulcan. The barbettes are built upon the citadel ends of the armored deck and are to be plated with 14 in. Harveyed steel. Upon their summits will be revolving armored hoods of sufficient capacity to hold the gun detachments working the guns by manual power, and as the barbettes are pear-shaped in plan, there will be room within the thin ends for the ordinary ammunition hoists and ramming gear required for fixed loading positions. There is, however, an axial ammunition trunk within the barbettes, which descends to the magazines direct, to which we shall advert presently. Another feature for the protection of the water-line is the filling in with water-tight divisions of the angular space between the curved edges of the armored deck and the lower streak of armor belting, thus forming a sort of cofferdam around the vessel at this level. A similar contrivance has been designed for some of the war vessels of France now under construction.

The secondary armament, consisting of 6-in. quick-firers, is all protected by 6-in. armor on the outside of the casemates and 2-in. plates on their other side. A valuable modification has been made in the arrangement of the upper deck battery. Instead of an open space, liable to be swept by the machine and quick-firing guns of the enemy, both from the armored tops and otherwise, this is now enclosed and decked over with a steel shelter deck, the four armored casemates at either corner acting moreover as screens to prevent a raking fire from either quarter. There is also beneath the forward bridge a flying deck, upon which light quick-firing guns will be placed. Above this towers the chart-room, rising to an altitude of 75 ft. from the under side of the keel. It is impossible to conceive anything more important to the steadiness and discipline of the guns' crews than the fact of their being able to fight their weapons behind adequate shelter, and this question has been thoroughly solved in the upper works of the Magnificent and Majestic.

The armament of these vessels and its disposition is as follows: Two 12-in. wire 50-ton guns are to be mounted upon each barbette, protected by a steel revolving hood, as in the case of the Barfleur and Renown. Beneath the turntables will be a revolving shell chamber, with an ammunition trunk in the center and hoists, so that loading can be carried out with the guns at any position of training. This is independent of the fixed loading positions, whose hoists are in the pear-shaped ends of the barbettes. Thus the rapidity of fire and of the serving of the ammunition are accentuated considerably by this twofold arrangement, not to speak of the value of an *alternative* system in the event of one having been placed *hors de combat* by accident. It will be observed that whilst the freeboard of the new vessels has been raised to a height of more than 20 ft. forward, the axis of the heavy guns has been also raised to 27 ft. above the water-line, being 4 ft. higher than in the case of the Royal Sovereign class. This will admit of the guns being fired axially forward or aft, without endangering the safety of the deck, an impossibility in the earlier vessels. Upon the main deck are eight 6-in. quick-firers in armored casemates, four on either broadside, and four more of these guns are upon the upper deck battery, one in an armored casemate at each corner, as will be seen in the engraving. The part of the shelter deck above these last-mentioned corner casemates is double plated to give additional strength. In the upper deck battery will be also twelve 12-pounder quick-firers upon shielded mountings, six on either broadside, and the remaining four 12-pounders will be forward and aft upon the superstructure. The two forward ones will be under the flying deck. Twelve 3-pounder quick-firers will be disposed upon the superstructure, tops, and in other situations. Eight machine guns will also be carried, and five torpedo tubes or dischargers. Two 12-in. guns, two 6-in. quick-firers, two 12-pounder, and seven or five 3-pounder quick-firers can be directed simultaneously either ahead or astern, whilst the broadside fired on either beam would be delivered from four 12-in., six 6-in. quick-firers, eight 12-pounder and eight 3-pounder quick-firers. In four minutes a weight of 30,000 lbs. of metal would thus be discharged from one broadside, whilst the corresponding figure forward or aft would be about 12,000 lbs. It must be borne in mind that all this concentration of fire has not been obtained, as in the case of the French battle-ships of the Charlemagne class, by fitting the guns into lateral grooves like the blades of a pocket knife, which must inevitably sacrifice the stability of the ship when axial fire is employed, but that each gun has a clear arc for itself without interfering with any adjacent works or with the rest of the armament.

The propelling machinery of the new vessels consists of two sets of engines of the ordinary inverted triple-expansion compound condensing type, the cylinders being 40 in., 59 in., and 88 in. in diameter respectively, by 51 in. stroke. The twin propellers are of gun-metal, and are 17 ft. in diameter and of 19 ft. 9 in. pitch. The boilers are eight in number, and are of the ordinary marine type, being 16 ft. 1 in. in diameter and

9 ft. 3 in. long, each containing four furnaces. They weigh about 50 tons each. The working pressure will be 150 lbs. per square inch. The main steam pipes will be of steel. The chief novelty in this connection is the application of induced instead of forced draught. The makers of the Magnificent's engines are Messrs. John Penn & Sons; those of the Majestic will be made at Barrow.

The two new battle-ships, although very fine in their lines forward and aft, are tolerably square at the midship section, the result being that their coefficient of fineness below the water-line area is .65 of a solid rectangle contained by the length, beam and draught.

The Magnificent was only laid down upon the 18th of December, 1893, and the Majestic upon the 5th of February, 1894; hence their readiness for floating out in so short a space of time is almost phenomenal.

Ammunition is supplied, save to the 12-pounder gun positions, through passages and trunks which are all either constructed of armor or are under protection. Beneath each gun position is an independent armored trunk, so that accidents from shells bursting between decks would be minimized in number and effects. The new ships will be fitted with two masts, with two fighting tops upon each. Each top will carry three 3-pounder quick-fire guns, with the necessary magazines and equipments. The mainmast will be fitted with a steel derrick 56 ft. long, for lifting the heavy boats into their positions on the skid beams over the upper deck. Each mast will also carry on a platform at its head a powerful electric light for signaling and searching purposes. The complement of boats is eighteen, four of which are steamboats, and will be capable of acting independently of the ship for purposes of torpedo attack, and four of the lighter boats will be carried on davits of special construction, which will enable them to be lowered at a moment's notice. The main and auxiliary condensers are formed of brass throughout, and possess a cooling surface of 13,500 square feet and 1800 square feet respectively.

In a comparison with the Charlemagne, the first feature that strikes one is that displacement and indicated horse power are nearly reversed as to their relative proportions; but, of course, the extra-engine power of the French vessel is mainly required for the third propeller, and we cannot admit that the result of experiments with triple-screw vessels is so satisfactory as to cause us a feeling of regret that more powerful engines have not been designed for the Magnificent class. At the same time if 18 or 18½ knots is got out of the Charlemagne by applying all her screw power, it will give her manœuvring qualities superior to those of the British battle-ships. This remains, however, to be proved.

The double-armored decks of the Charlemagne are a valuable modification, and the cofferdam between them may prove to be a most useful adjunct to the water-tight qualities of the ship; but it seems to us that, if the stability of the vessel was not disturbed by the arrangement, the two decks would have been more effective combined in one thickness. The turtle-back deck of the Magnificent, stretching from bow to stern, and reaching down far over the sides amidships, with its four inches of steel, is superior, we believe, to the French cofferdam.

The method by which axial fire ahead and astern has been secured appears so likely to be detrimental to the safety of the vessel's upper works when the guns are trained directly fore and aft, that we cannot recommend it. But the plan of securing the upper deck battery of

5½-in. guns behind a complete belt of 3-in. armor cannot be too highly approved. The conning towers are also well placed and at a commanding altitude, though it is a little difficult to understand what security is afforded to the officers in the forward one, in the event of the mast being shot away upon which it is perched, the latter not being armored.

The power of the armament mounted upon the Magnificent is incomparably superior to that of the French vessel. The twelve 6-in. quick-firers upon the former, each with its isolated casemate protected by 6-in. steel, and the sixteen 12-pounder quick-firers of the new Elswick pattern, compose an auxiliary armament so tremendous in its potency that no moderate-sized cruiser could live in the vicinity of the battle-ship, even if keeping under weigh at a rapid rate of steaming, so as to avoid the fire of the main armament of 12-in. heavy guns. The uniform height, 27 ft., of the British heavy guns above the water-line is also a distinct advantage.

The total coal capacity, and consequent radius of action of the British battle-ship, is considerably greater than that of the Charlemagne. Eighteen hundred tons of coal can, in emergency, be stowed away in the former, but the extreme capacity of the latter is only 1100. This is an important characteristic for long sea voyages.

THE TORPEDO-BOAT DESTROYER BRUIZER.

On March 28, in boisterous weather, a full-speed official trial was run of the last of the torpedo-boat destroyers which Messrs. Thornycroft & Co. have built for the Admiralty. The trial was not notable on account of the speed attained, but that is simply on account of the high standard which the builders themselves have raised for these remarkable craft. A short time ago 28 knots, which the Bruizer all but attained on her three hours' run, would have been looked upon as phenomenal; but it has been exceeded by about a knot in the sister vessel, the Boxer, also constructed at the Chiswick yard.

The Bruizer is 201 ft. 6 in. long and 19 ft. wide; she is 13 ft. deep, and her maximum draught is 7 ft. 4 in. at trial draught. The displacement of the vessels of this class is about 220 tons. The engines are similar to those of the Daring. These engines are of quite novel design, and now the trials of the five destroyers in which they have been fitted are complete, it is satisfactory to learn that the engines have given no trouble throughout. The same may be said of the water-tube boilers which have been fitted in these vessels. There have been run, in all, 23 full-speed trials of these vessels, and there has not been an accident or mishap through the failure of the boilers throughout. The fact is of interest in view of the controversy now going on on the subject of water-tube boilers. The enormous test that the machinery of these high-speed craft is put to on full-speed trials must be remembered in connection with this subject. The Bruizer has three Thornycroft boilers placed in two stokeholds. A modified design of Daring boiler is used, the arrangement being the same as that adopted in the Ardent, by which an addition to the heating surface is obtained by a somewhat different disposition of the tubes in the rows next to the casing. The Daring had 8892 square feet of heating surface and 189 square feet of grate surface.

The engines of all these vessels are of the three-stage compound type, each set having high-pressure cylinders 19 in. in diameter, intermediate cylinders 27 in. in diameter, and two low-pressure cylinders each of 27 in. diameter. The stroke is 16 in.

In the Speedy a new device was tried for controlling the distribution of the feed in the water-tube boilers with which that vessel was fitted. It is this question of feed distribution which was so long the rock ahead for the water-tubists when an attempt was made to run these boilers in groups. It was argued, not without reason, that in steam generators of this sensitive nature, and with so small a water-holding capacity, unless the feed were very evenly distributed, disaster would follow. In order to avoid this various devices have been tried, with more or less success. That introduced by Messrs. Thornycroft consists of a hollow steel float, capable of withstanding the boiler pressure, which is placed inside the separator or steam-connecting cylinder which forms so important a feature in the Thornycroft boiler. By a system of levers, somewhat too complicated to describe without the aid of diagrams, the float regulates the opening of a check valve which is placed within the boiler, the amount the valve is opened determining the volume of feed. In this way the water-level in the boiler determines the amount of feed admitted; thus, if the water level falls, the check valve is thrown wider open; if it rise the check valve is closed. Unlike most gears of the kind, the motion of the float has not to be conveyed to the exterior of the boiler through a stuffing box. An arrangement of the latter nature must lose much of its sensitiveness, and herein the Thornycroft gear has a manifest advantage. There is, however, in this device a means of regulating the normal water level by hand, and this is effected through a rod which passes outside the separator through a stuffing box and is worked by a hand wheel. In this way the gear may be set so that the water level can be carried at any required height. The gear has, we hear, been found in practice to act admirably, and we understand it is contemplated using it in some vessels built by other firms. On the occasion of the Bruizer's trial on March 28, the feed water between the three boilers was properly distributed by it, the report being that no hand adjustment was required throughout.

The Bruizer differs from the earlier vessels of this class in having solid manganese bronze propellers. It has long been the practice of the torpedo-boat builders to forge the propeller blades separately and key them into a boss. This plan answered well so long as steel blades only were used, but when manganese bronze was required it was found there was danger of the blades getting loose in the boss. In order to avoid this, a new method of keying it was devised, but it is now thought desirable to have the propellers cast in one. The screws of the Bruizer are three-bladed, all surfaces being polished.

The furnace doors are fitted with springs so as to be self-closing, and the ash-pit doors being self-closing there is less danger to the stokers in case of a burst tube, as the steam would go up the chimney.

At the conclusion of the speed trials, circles were turned on both hands. The circle with helm to port was accomplished in 1 minute 46 seconds, with the helm to starboard in 1 minute 52 seconds. This was in a strong wind, the force being 5 to 6. The weather was too rough to make circles astern, so that part of the trial is reserved for another time.

THE BANSHEE AND CONTEST.

Her Majesty's ships Banshee and Contest, two of the torpedo-boat destroyers building for the British Government by Messrs. Laird Brothers, of Birkenhead, have completed their official trials on the measured mile on the Clyde, and the contractors have to be congratulated on highly satisfactory results. Messrs. Laird have availed to the fullest extent in designing the hulls and machinery of these vessels of their past experience with high-speed ships, with which they have had an unbroken line of successes, including her Majesty's ships Rattlesnake, Onyx, and Renard; the Almirante Lynch and Almirante Condell, for the Chilian navy; the Espora and Rosales, for the Argentine navy; and the machinery they fitted to her Majesty's ships Skipjack and Speedwell; and more particularly they have followed the information obtained in connection with her Majesty's ships Ferret and Lynx, the two torpedo-boat destroyers which they successfully tried and delivered in the summer of last year. The Banshee and Contest are 210 ft. long with 19½ ft. beam, and generally similar in construction to the Ferret and Lynx, which we described in our issue of 7th September last. The armament, however, has been modified, and now consists of one 12-pounder and five 6-pounder quick-firing guns, two separate torpedo tubes on the deck, and no bow tube, and they are equipped with the latest type of 18-in. torpedoes. The engines are Messrs. Laird's well-known tri-compound type, the cylinders being 19 in., 29 in., and 43 in. in diameter by 18 in. stroke, and it is worthy of notice that all parts of the engines are accessible when working at full speed, and all the starting and reversing gear, etc., is worked from a platform at the forward end of the engine-room. It has been a very satisfactory feature in the machinery of Messrs. Laird's make that they have designed their engines with cylinders large enough to give the required power at a reasonable number of revolutions, and on the trial of the Banshee the average for the three hours was only 345. The boilers are a modified form of the Normand type, and no difficulty was experienced throughout the three hours' trial in maintaining the steam at the intended pressure. There was no indication of priming either on the official or preliminary trials.

The official trial of the Banshee took place on Thursday, February 21st. The three hours' trial was commenced at eleven o'clock, the vessel having on board her full normal weight, and the average speed for the whole time was found to be 27.6 knots, or 31.8 miles per hour, with 345 revolutions. After the run the usual trials as to manœuvring were made. The helm was put from hard over to hard over both ways in less than ten seconds, each at full speed, and the steering both ahead and astern was proved to be entirely satisfactory. The trial of the Contest was made under similar conditions the following day, and the mean speed for the three hours was 27.4 knots, with 350 revolutions. There was a remarkable absence of vibration when running at full speed, and no hitch of any kind occurred in the machinery. The seagoing qualities of these boats are perhaps as interesting as the mere speed. An illustration of their success in this direction has been afforded by the Banshee and Contest. The first left Birkenhead under easy steam at 3 P. M. on Friday, February 14th, and reached Greenock at 3 o'clock next morning, in spite of a heavy southeast gale which prevailed from the Mull of Galloway onwards.

The Contest left Birkenhead on February 19th, at 7.15 A. M., and reached Greenock at 4.50 the same afternoon—over twenty knots average—and the vessels were got ready for trial and all the weights adjusted as recorded above. Messrs. Laird only received the order for these boats in February of last year, and the rapidity with which they have been brought forward for trial is highly creditable, and it showed great confidence in the machinery to make the trials of two such boats on successive days, especially as the Banshee had only been twice and the Contest only once under weigh before leaving the Mersey to make their trials. The third boat of the lot is named the Dragon, and is now ready for steam, and will be tried very shortly.

THE ROCKET AND SHARK.

While such high speeds as 28 knots were attained with these and the other vessels constructed by Messrs. James and George Thomson, Limited, Clydebank, on experimental runs, the firm, on the official trials which have just been concluded, contented themselves by just exceeding their guarantee. Thus, having ascertained that 396 revolutions per minute insured 27 knots under all conditions of weather and full displacement, they decided not to go far beyond this. The mean results of the six runs on the measured mile, three in each direction, may be thus tabulated:

MEANS OF SIX RUNS ON MEASURED MILE.

	Rocket.	Shark.
Date of trial	Feb. 27.	March 1.
Air pressure in stokehold	3.5 in.	3 in.
Steam pressure at boilers	188 lbs.	184 lbs.
Revolutions, port engine	399	400
Revolutions, starboard engine	397	397
Vacuum	25 in.	25 in.
Speed of boat	27.7 knots.	27.5 knots.

On the three hours' run in the Firth, with full weights on board, indicator diagrams were taken every quarter-hour, and the results were as follows, the speed being determined by the mean revolutions of the engines:

	Rocket.	Shark.
Revolutions of engines	396	401
Speed of boat	27.4 knots.	27.6 knots.
Indicated horse power	4200	4250

One feature of special note is the wave line. The Rocket and her consorts have an exceptionally fine entry, with a flat floor and little tumble home amidships. The stem is straight. In this respect she differs from some of the earlier craft, which had a torpedo-ejecting tube firing straight ahead; but it was found in practice that the impact of the torpedo on the water retarded it so much as to cause the destroyer, when steaming 27 knots, to overrun it. The later vessels, therefore, have only a double torpedo launching gun on deck, and the change has enabled greater accommodation to be provided for the crew, under the turtle-decked forecastle-head, where there will be mounted a 12-pounder quick-firing gun over the conning tower, with two 6-pounder guns on either side behind the shelter of the forecastle. The deadwood between the outboard propeller shafting is cut away, so as to afford a freer flow of water to the twin propellers, which are of manganese bronze. The rudder is of the usual type, supported on the usual pintle, the lesser depth being compensated for by greater width.

The machinery consists of two sets of triple-expansion engines. All the working parts are of forged steel and are balanced. The cylinders are supported on steel columns, thoroughly braced, the condenser being separated. The engines were run at a high speed in the erecting shop to ascertain the efficiency of the balancing, and the results on trial were satisfactory. The high-pressure cylinders are 18⅛ ins. in diameter, the intermediate 26⅝ in., and the low pressure 40⅛ in., the stroke being 1 ft. 6 in. The piston speed on trial was therefore about 1200 ft. per minute.

There are four water-tube boilers of the Normand type, but it may be here stated that they have two water drums on either side, with the fire-grate between, and from these two drums there are tubes extending in curves of many forms to a central steam drum on the top, the tubes entering in the lower part of the steam receiver or below the water level. The tubes in the rows nearest the fire are of steel, the others are of copper. At the back of the grate the tubes are so curved as to partly close in the furnace end, and in addition the tubes are arranged to prevent the hot gases escaping before the greater portion of the heat has been absorbed. The outside walls consist of galvanized steel tubes. The boilers practically occupy the full size of the compartments, which are covered with a heat-resisting substance placed under the deck. The grate area is 163 square feet and the heating surface 8600 square feet, so that the power was equal to 26.07 indicated horse power per square foot of grate area and to 1 horse power per 2.02 square feet of heating surface. The two center boilers have a smokestack in common, while the forward and after boilers have separate funnels smaller than the center funnel. The engines are abaft the boiler compartments.

[SPAIN.]

THE EMPERADOR CARLOS V.

There was launched on March 12, at Cadiz, a first-class protected cruiser for the Spanish Navy.

The displacement of the vessel will be, in sea trim, 9089 tons, the length between perpendiculars being 380 ft., and over all 404 ft. 9 in., the beam 67 ft., and the draught 24 ft. forward, 26 ft. aft and 25 ft. mean. The hull has been built by Messrs. Vea Murgia and Co., Siemens-Martin steel being used, and there is side armor 2 in. thick, 1 in. of Siemens-Martin steel, and the other inch of chrome steel. The protective deck is of steel, the maximum thickness being 6⅛ in., made up of three plates. The armament consists of two 28-centimeter Hontoria guns, eight 14-centimeter Hontoria quick-firing guns, four 10-centimeter and two 7-

centimeter quick-firing guns, four 57-millimeter and four 37-millimeter Nordenfelt guns, two machine guns (mitrailleuse), and six Schwartzkopff torpedo tubes.

The twin engines are of the four-cylinder triple-expansion type, there being two 25-in. high-pressure cylinders, two 77 3-16-in. intermediate, and four 82 3-32-in. low-pressure cylinders, the piston stroke being 45 5-16-in. Steam at 147 lbs. pressure is supplied by 12 single-ended boilers, 16 ft. 3⅝ in. in diameter by 9 ft. 10⅛ in. long. Under natural draught the power to be developed is 15,000 indicated horse power, and under forced draught 18,500 indicated horse power, the speed being, under the former conditions 19 knots and under the latter 20 knots. The screw propellers, which are of bronze, have each four blades. The vessel has bunker capacity for 1771 tons, which gives her a radius of action of 13,000 sea miles at 10 knots. The machinery was constructed by the Maguinista Terrestre y Maritima, Barcelona. The cost of the vessel is about $3,400,000.

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[AMERICAN.]

ARMY AND NAVY JOURNAL.

APRIL 20. Lessons of the Yalu.

APRIL 27. Advantages of Double Turrets. Modern Warships. The Chinese Surrender.

MAY 25. Lessons of the Chino-Japanese War.

ARMY AND NAVY REGISTER.

MAY 4. More Excellent Armor.

MAY 25. Naval Small Arm Adopted.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

MARCH. Constitution and List of Members.

THE AMERICAN ENGINEER AND RAILROAD JOURNAL.

APRIL. Physical Reasons for Rapid Corrosion of Steel Boiler Tubes. Some Facts Relating to Certain Types of Water-tube Boilers. The Cruiser Cincinnati. Tests of the Pneumatic Guns.

MAY. Water Tube Boilers in the British Navy. Some Experiments on the Efficiency of Air Propellers.

AMERICAN CHEMICAL JOURNAL.

APRIL. Argon, a New Constituent of the Atmosphere, by Lord Rayleigh, Sec. R. S., and William Ramsay, F. R. S. On the Spectra of Argon, by William Crookes, F. R. S., etc. The Liquefaction and Solidification of Argon, by K. Olszewski, Professor of Chemistry in the University of Cracow. On the Atomic Weight of Argon, by Edward W. Morley.

The symbol A has been proposed for argon on the supposition that it is an element which is not definitely proven, its spectrum consisting of two distinct combinations of lines.

BULLETIN OF THE AMERICAN GEOGRAPHICAL SOCIETY.

VOLUME XXVII., No. 1, 1895. Korea and the Koreans. The Mapping of New York State. Reports of a Conference on Geography. The United States Geological Survey in 1894.

CASSIER'S MAGAZINE.

MAY. The Telephone and Its Operation. Telegraphy as It Used to Be. American Coast Defense Mortars. A History of the Telephone.

ENGINEERING NEWS.

MAY 2. The Location of the Nicaragua Canal. Legal Electrical Units in the United States.

MAY 9. The French Aluminum Torpedo-boat.

IRON AGE.

FEBRUARY 28. The Uehling and Steinbart Pneumatic Pyrometer. Reduced Harveyized Armor Plate.

MARCH 7. The Great Gun Magnet. Tests of Non-conducting Pipe Coverings.

MARCH 14. The Higgins Plate Roller Bending Machine.

MARCH 21. The Bristol Recording Ampère Meter. Southern Coal Tests by the Navy Department. Electric Annealing of Armor Plate. Naval News.

APRIL 11. The Carnegie Armor Plate Test.

The Navy Department at Washington has issued the following statement of the present condition of the new United States war vessels. The figures represent the percentage of completion: Amphitrite, 99 per cent.; Maine, 98 per cent.; Terror, 96 per cent.; Texas, 95 per cent.; Indiana, 93 per cent.; Massachusetts, 90 per cent.; Katahdin, 90 per cent.; Oregon, 89 per cent.; Puritan, 87 per cent.; Monadnock, 85 per cent.; Brooklyn, 42 per cent.; Iowa, 35 per cent.; Gunboat No. 7, 31 per cent.; Gunboat No. 9, 26 per cent., and Gunboat No. 8, 25 per cent. Since January 1 the Minneapolis, Cincinnati, Raleigh, Olympia, and Ericsson have been taken from the list of uncompleted ships. All have been commissioned and put into regular service except the Ericsson. The Amphitrite will be commissioned next week, leaving but 14 naval vessels under construction.

APRIL 25. The Sprague Electric Locomotive. Defects in Steam Boilers, III.

MAY 2. Captain Eardley-Wilmot on the United States Navy.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

MARCH. Discipline: Its Importance to an Armed Force, and the Best Means of Promoting and Maintaining it in the U. S. Army. Preliminary Examination: West Point. The Place of Physical Training in the Military Service. The Royal Artillery College at Woolwich. The Infantry Drill Regulations Systematized and Simplified. Comment and Criticism. The Military Academy and the Education of Officers.

"One essential truth must be borne in mind, namely, that all educational institutions of the highest order are growths and not Minerva-like creations."—[Prof. Charles W. Larned, U. S. M. A.]

"West Point does not educate anybody. That is impossible in four years at any liberal institution. What, from an educational standpoint, it does and successfully is to give the cadet the basis of an education." —[First Lieut. W. E. Birkhimer, Adjutant, 3d U. S. Artillery.]

Range and Position Finding. The War between China and Japan.

MAY. A Paper on Military Libraries. The Relation of Hygiene to Military Efficiency. The Army Artillery Reserve. Training of the American Soldier. Results of Experimental Firing with the Service Rifle (Model of 1894). Battery Competitions for Gunners. The United States Marine Corps. Value of the Fire of Dismounted Cavalry. "The Right (or Left) Turn" of the Infantry Drill Regulations. Comment and Criticism. Reprints and Translations.

JOURNAL OF THE UNITED STATES CAVALRY ASSOCIATION.

MARCH. High Explosives and Intrenching Tools in their Relation to Cavalry.

JOURNAL OF THE FRANKLIN INSTITUTE.

MARCH. The Animal as a Prime Mover, Part III., by R. H. Thurston. Action of a Single Phase Synchronous Motor. Water Purification. Science in the Foundry.

APRIL. The Redheffer Perpetual Motion Machine. The Rise and Progress of River and Harbor Improvement in the United States. The Atomic Weight of Tungsten. The Reduction of Alumina from a Thermo-chemical Standpoint.

JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JANUARY. Tests of Non-conducting Pipe Coverings.

SCHOOL OF MINES QUARTERLY.

JANUARY. Theory of Electro-metallurgy.

THE UNITED SERVICE.

MARCH. The Supply of the Armies of Frederick the Great and Napoleon. The Story of Alcatraz. Origin and Developments of Steam Navigation (continued).

APRIL. The Supply, etc. (continued). Yesterday in Annapolis. Origin, etc.

MAY. The Supply, etc. (concluded). Origin, etc. (concluded).

[FOREIGN.]

ENGINEER.

NO. 2042, FEBRUARY 15. Report on a Pumping Engine at Hornsey Sluice. Destruction of Chinese Warships at Wei-Hai-Wei. Priming and Governing Engines.

FEBRUARY 22. The New Elswick Eight-inch Quick-fire Gun.

MARCH 1. Trial Trips of the Banshee and Contest. Electric Light Engines and Dynamos, S. S. Caledonia.

"It has a drum armature rotating between the poles of a vertical horseshoe magnet, and will give an output of 220 amperes at 105 volts when running at a speed of 220 revolutions per minute."

MARCH 8. The Utilization of Niagara. The Admiralty Distribution of Engineers in the Fleet.

MARCH 15. The Navy Estimates. Static Friction.

MARCH 29. The Battle-ships Magnificent and Charlemagne—a Comparison.

APRIL 5. Elements of Force in a Warship (Inst. Naval Architects).

APRIL 12. First-Class Battle-ships and Bilge Keels.

"To sum up, then, the bilge keel has proved itself to be an instrument capable of reducing the extent of rolling from 50 to 70 per cent.; of accelerating the process of extinction of rolling sixfold; of increasing the rolling period so as to enhance steadiness; of developing to its fullest extent the value of headway in assisting steadiness, and of reducing materially the tactical diameter in turning, as well as improving steering properties, whilst speed is uninjured and coal endurance not affected. The result of these experimental trials is therefore phenomenally satisfactory."

APRIL 19. British Fuzes for Modern Guns.

ENGINEERING.

No. 1520, FEBRUARY 15. The New Nordenfelt Guns. The Pneumatic Pyrometer. The Cost of Vessels of the Naval Defense Act.

FEBRUARY 22. The New Nordenfelt Guns (continued).

MARCH 1. The New Nordenfelt Guns (continued). The Naval Manœuvres (1894).

MARCH 8. The New Nordenfelt Guns (continued). Short Air-Space Dynamos. The Torpedo-boat Destroyers Rocket and Shark.

MARCH 15. A Review of "Elementary Naval Tactics," by Commander William Bainbridge-Hoff, U. S. Navy.

"The United States Navy is fortunate in possessing officers who are not merely good sailors and brave men, but are also acute and able thinkers, and have the power of expressing their ideas in clear, concise and forcible language. The system of education in the American Navy is perhaps better adapted than our own for creating a corps of officers who will be men of thought as well as men of action; and one natural outcome of it is seen in the many erudite and exhaustive books and papers upon naval questions which come from the pens of American naval officers. Their literary work appears to be marked by more thoroughness, better balance and greater power of thought, analysis and expression than we in this country are accustomed to expect from naval authors."

The New Nordenfelt Guns (continued). The Navy Estimates.

MARCH 22. The New Nordenfelt Guns (continued). The New Spanish Cruiser Emperador Carlos V. The Navy in Parliament.

MARCH 29. The New Nordenfelt Guns (continued).

APRIL 5. Torpedo-boat Destroyers. Our Battle-ships (Notes on Further Experience with First-class Battle-ships), by Sir William White, Director of Naval Construction (British).

"The Resolution (without bilge keels), by orders from the Admiralty, had been purposely kept in very nearly the same condition of stability as the Repulse. Comparing the returns from these two ships, it appears that the Resolution on one occasion reached a maximum inclination to the vertical of 23 deg.; whereas the Repulse never exceeded 11 deg. The mean angles of oscillation were, of course, considerably below these maxima, probably about one-half. The Royal Sovereign and Empress of India were also in company. The condition of coal storage in these two ships at the time gave them greater stiffness and a quicker period, which, under the conditions of weather and sea, caused rather heavier rolling than in the Resolution.

In view of this experience, although the trial was limited and not representative of many conditions occurring at sea, it was decided to fit all the other ships of the class with bilge keels similar to those which had proved so effective in the Repulse. This work was completed for the ships of the Channel Squadron during their annual refit last summer; it has since been carried out in all the other ships of the class.

On the cruises of the Channel Squadron which have taken place since bilge keels were fitted there have been but few opportunities of obtaining proof of their practical value. So far as experience has gone, however, there is a consensus of opinion amongst officers in command that rolling has been greatly reduced by the bilge keels."

H. M. S. Bruizer.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

MARCH. Battles of Chillianwallah and Goojerat. The New Harbor at Biserta, with Plans.

APRIL. Sir George Rooke, Admiral of the Fleet. Collapsible Boats and Pontoons for Military Purposes, by the Rev. E. L. Berthon. The Hydraulic Gun-mounting of French Ships.

MINUTES OF PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS.

VOLUME CXIX., 1894-95, Part 1. The Machinery of Warships. Indian River Steamers. The Filtration of the Müggel Lake Water Supply, Berlin.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

FEBRUARY. A Method of Calculating the Probability of Coast Defense Fire. A Plea for Heavy Guns in Fortress Defense. Notes on German Manœuvres.

MARCH. The Story of the Civil War in America (A Review). General Bourbaki's Campaign in January and February, 1871. The Resistance of the Air at High Velocities, by Captain Zabudski, Russian Artillery (Translated from the Russian).

Captain Zabudski uses Krupp's tables in his calculations to continue Mayevski's laws.

With the metre and kilogramme as units:

From $v =$ 1000 m. s.	to $v =$	800 m. s.,		resistance $=$	$q = 0.7130\pi R^2 \frac{\delta}{\delta_0} v^{1.55}$,
800	" "	550	"	"	$q = 0.2616\pi R^2 \frac{\delta}{\delta_0} v^{1.70}$,
550	" "	419	"	"	$q = 0.0394\pi R^2 \frac{\delta}{\delta_0} v^2$,
419	" "	375	"	"	$q = 0.0^{4}940\pi R^2 \frac{\delta}{\delta_0} v^3$,
375	" "	295	"	"	$q = 0.0^{9}670\pi R^2 \frac{\delta}{\delta_0} v^5$,
295	" "	240	"	"	$q = 0.0^{4}583\pi R^2 \frac{\delta}{\delta_0} v^3$,
240 downwards				"	$q = 0.0140\pi R^2 \frac{\delta}{\delta_0} v^2$,

Where R is the radius of the cylindrical part of the projectile in metres, δ is the density of the air during the experiment, and δ_0 is the standard density of 1.206 kilogrammes per cubic metre.

Captain Zabudski calculates the values of his ballistic functions between 600 m. s. and 1000 m. s. by the equation $q = 0.5091\pi R \frac{\delta}{2\delta_0} v^{1.6}$; which is sufficiently approximate.

APRIL. Coast Artillery in Action. Torpedo-boat Raids on Harbors.

STEAMSHIP.

MAY. The New First-Class Cruisers (British).

Provision is made for the commencement of four new first-class cruisers in the navy estimates for 1895-96. The principal dimensions are: Length between perpendiculars, 435 ft.; on water-line, 455 ft.; breadth, 69 ft.; mean draught with keel, 25 ft. 3 in.; displacement about 11,000 tons. The measured mile speed, natural draught, will be about 20½ knots.

THE UNITED SERVICE GAZETTE.

NO. 3240, FEBRUARY 9. The Navy League. China and Japan. The Tactics of the Corean War, by Vice-Admiral P. H. Colomb.

"The results of the Yalu battle were the same as that of the battle of the Nile. The Chinese had no business to send a great fleet on a secondary expedition. If competent to contend for the command of the sea, it might have been used for that purpose, and no other; if not competent, it ought to have been kept intact to make it more difficult for the Japanese to follow up with attacks upon territory."

FEBRUARY 16. China and Japan. What is a Sufficient Navy?

FEBRUARY 23. The Halpine Dirigible Torpedo. Naval Reserves.

MARCH 2. The Naval Manœuvres, 1894. How Can the Navy be Made Ready for War? Fighting on the Niger.

MARCH 9. The Navy Estimates, I. The Army Estimates. Heavy Guns in Fortress Defense.

No provision is made in the Navy estimates for the commencement of any new battle-ship in the coming financial year.

MARCH 16. The Navy Estimates, II. Naval Policy. The Organization of the Navy for War.

MARCH 23. The Royal Dock Yards; New Programme for Work. The Requisite Strength of the British Navy.

APRIL 6. Our Strategic Position in the Mediterranean. The Chitral Expedition.

APRIL 13. Warship Construction. Torpedo-boat Destroyers.

APRIL 20. Messenger Pigeons in Connection with Coast Defense (a summary of the paper published in No. 72 of the Proceedings U. S. Naval Institute). The Fighting Coefficients of a Warship.

APRIL 27. The Navy as the Empire's Representative. The "Times" and the War Office.

MAY 4. The Navy Boiler of the Future. The "Times" and the War Office, II.
J. H. G.

LE MONITEUR DE LA FLOTTE.

FEBRUARY 2. The New Minister of Marine, Vice-Admiral Besnard.

FEBRUARY 9. The Madagascar Transports.

FEBRUARY 16. The Re-establishment of the French Board of Admiralty. The Extra-Parliamentary Naval Committee.

FEBRUARY 23. The Creation of a List of Commands.

MARCH 2. The Growing Importance of the German Navy.

MARCH 9. Our Navy at Kiel.

MARCH 16. French and English Battle-ships. The Naval Estimates.

MARCH 23. The Discussion of the Navy Estimates.

MARCH 30. Running Lights.

"The question of safety of navigation is one of daily recurrence, which recent disasters have only served to intensify. Rear-Admiral Galoche, in an article in the La Marine Française, proposes a change which he thinks will tend to remedy the insufficiency of the existing running lights. In the proposed system the light at the masthead, instead of a sector of 10 points of white light on each side, will only have a white sector of 4 points, continued by a sector of 6 points of green light on the starboard side and a sector of 6 points of red light on the port side.

The immediate results of the use of this tri-color masthead light can be easily conceived. 1st. When a vessel sights another showing a white and colored light, the first will be inside of 45° of the other's course, reckoning the bearing from right or left, according to the color of the side light. 2d. When in the presence of a vessel showing two lights of the same color one will find himself outside of the 45° of the route of the stranger and consequently in no danger of a collision. If, being in the first position, a manœuvre is made which will bring out the lights of the second position, a feeling of safety will at once follow. If, on the contrary, finding oneself in the second position (*i. e.* with two lights of the same color in sight), a manœuvre will bring in the white sector, it is presumable that the ships are approaching one another. Thus the simple use of a tri-color light, easy of construction and management, diminishes notably the sector of the possible routes of a ship in sight and gives the watch officer the means of reckoning these routes rapidly and *de visu* within far more restricted limits than with the white light."

REVUE DU CERCLE MILITAIRE.

FEBRUARY 2. A Safety Device for Preventing Premature Firing (with sketches). Cavalry Confronted by the New Fire-arms. Long Distance Photography (with sketches) (continued).

FEBRUARY 9-16. The Japanese Army. The Thirteenth French Army Corps in the War of 1870. Long Distance Photography (ended).

FEBRUARY 23. The Lefebvre Carriages and the Madagascar Expeditionary Corps. Ice-shoeing of Horses in Sweden and Norway.

MARCH 9. Madagascar: Its Geography, Climate, Population and Productions. The Lefebvre Conveyance, and the Madagascar Expeditionary Corps. The Thirteenth Army Corps in the War of 1870 (continued).

MARCH 16-23. Medical Statistics of the French Army for 1892. Madagascar, etc. (continued). The Thirteenth Army Corps, etc. (continued).

MARCH 30. The Holy City of Moukden. The Thirteenth Army Corps, etc. (continued).

REVUE MARITIME ET COLONIALE.

JANUARY. The Naval Battle of Yalu, according to the Latest French and Foreign Informations, by Lieut. Lephoy, of the French Navy. In what Consist our Armored Battle-ships, and their Worth. The Cruiser Volta in China and Tonkin (1883-85). Chemical and Micro-biological Researches in the Alterations and Protection of Common Metals in Salt Water. Prizes for the Best Works Published in the Review.

FEBRUARY. The First-class Torpedo-gunboats of the English Navy. A Report on the Process used for Detecting Fraud in Table Oils and in Oils used in Manufacture. A Study of the Modern Mounts for Heavy Ordnance. Geometry of Diagrams (continued).

SOCIÉTÉ DES INGÉNIEURS CIVILS.

JANUARY. Mechanical Traction of Boats on Canals. Electro-Magnetic Towing. A Study of Various Electric Plants in Switzerland and Savoy. Comparative Results of Electricity and Compressed Air in the Mechanical Traction of Tramways.

FEBRUARY. A New Process for Calculating the Strain Sustained by a Latticed Straight Beam Symmetrically Laden and Resting on Two Supports. Annual of 1895 (a supplement to the January number).

LE YACHT.

FEBRUARY 2. The End of the Flying Squadron.

"After giving this method of instruction a two years' trial the naval authority became convinced that its advantages over the old method were not such as to justify its continuation at the greatly increased cost."

Union of the French Yachts: Admissions, Concessions of Flags, etc. Association Technique Maritime: Remarks on the Fire-boxes of Boilers (Daymard).

FEBRUARY 9. The Question of Transportation to Madagascar.

FEBRUARY 16. The Destruction of the Chinese Fleet (E. Weyl). Submarine Telegraphy.

FEBRUARY 23. The Question of Transports.

MARCH 2. Commerce Destroyers (Privateer-cruisers) (E. Weyl). Electricity: Telegraphic Communications without an Intermediary Conductor (Em. Cohen).

MARCH 9. The Question of Battle-ships. The Italian Torpedo-ram Umbria.

MARCH 16. The English Navy Appropriations.

"The amount of the English Navy estimates for 1895-96 is £18,880,021 ($91,379,301), an increase of $6,741,045 over last year's and an increase of about twenty-two and a half millions over the preceding year, besides a supplementary credit of $22,000,000 spent for the purchase of raw material and supplies in order to take advantage of the decline in market prices.

The total personnel afloat in 1895-96 will be 88,850 men, an increase of 5,450 over the present year, which has already an increase of over six thousand over the preceding one. The increase of men is particularly noticeable in the number of machinists, firemen, etc., which is only natural in view of the enormous development of steam power. It may be thus seen that Great Britain, far from thinking of ever abandoning her supremacy of the sea, will at no distant date have an enormous navy so powerfully constituted as to defy the whole naval world combined."

MARCH 23. The Navy in the French Chamber of Deputies.

"In 1891 the High Council of the Navy fixed the composition of our fighting squadrons as follows: 24 armored battle-ships, 12 first-class cruisers; 12 second-class cruisers, 12 third-class cruisers, 4 supply transports, 4 torpedo transport cruisers, 2 repair-shop cruisers, 12 cruisers or large torpedo despatch-boats, 40 seagoing torpedo-boats, 45 embarkable torpedo-boats, besides a number of coast defense vessels and a fleet for foreign stations. But in 1894 the High Council, presided over by M. Felix Faure, since elevated to the dignity of President of the Republic, decided that the Squadron of First Class Cruisers should be composed of armored cruisers, the number of which should be raised to twelve by the construction of six additional vessels of the type of the Dupuy-de-Lôme, with displacements of not more than 8000 tons, keeping in view (1) Radius of action; (2) Speed; (3) Offensive power, and, finally, Defensive Power. The number of second-class cruisers being now complete owing to the disrating of protected cruisers ranking at present as first-class, none will be built till 1904. Supply transports and repair-shop vessels are done away with. The seagoing torpedo-boats having proved inefficient while accompanying squadrons, will be turned over to the mobile defenses as soon as the 220-ton boats are finished. Reductions are also made in the number of coast defense vessels, besides other secondary modifications of the original plans. This will involve an expenditure of about 214,200,000 francs, distributed over a period of nine years."

Launching of the Spanish Armored Cruiser Carlos V., of 9235 Tons Displacement.

MARCH 30. The Navy in the House of Commons (E. Weyl). The Bulb-keel. Launching of the Russian Imperial Yacht Standart.

RIVISTA DI ARTIGLIERIA E GENIO.

VOLUME I., JANUARY. Notes Relative to the Theory of the Resistance of Straight Beams Subjected to Longitudinal Pressure. Progress and Regress of the Infantry Rifle. On the Factors of Fire through Quadratic Resistance. On the Probability of Fire in Coast Artillery.

FEBRUARY. A Glance at the European Small Fire-arms.

In a lengthy article on the modern rifle, the writer states that no nation can boast of a weapon really superior to that of another, but still he thinks a preference may be given to the Mauser, Roumanian model of 1893, 6.5 mm. calibre. The general tendency to decrease the calibre of the gun has induced France, though possessing a superior weapon in the Lebel, to replace the latter by the Dauteteau rifle of 6 mm.

MARCH. A Table of Fire (v. Fattori di tiro in the preceding Vol.). A Few Observations in Regard to the Manuals of Temporary Fortifications. The Characteristics of Coast Firing. The Actual State of the Question of Field Guns.

RIVISTA MARITTIMA.

VOLUME II., FEBRUARY. Erosion in Steam Boilers and Ship Bottoms. A History of the Italian Navy from the Time of Cosmo I. and his Immediate Successors. Coastwise Navigation in the Adriatic Sea.

The writer laments the fact that the coast trade of this pre-eminently Italian sea is practically carried on by Austrian shipowners.

REVISTA TECNOLÓGICO-INDUSTRIAL.

FEBRUARY. Analysis of the Flour of Commerce (ended). An Aluminum Torpedo-boat.

MARCH. Something on Hydraulics. Inter-urban Telephones in Spain.

REVISTA MARITIMA BRAZILEIRA.

JUNE, 1893—DECEMBER, 1894. Reorganization of the Brazilian Navy.

JANUARY, 1895. Autobiography of a Whitehead Torpedo (v. preceding No.). Construction of Guns of the Armstrong System. Reorganization of the Brazilian Navy (continued). J. L.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

ANNUAL SERIES XXIII., VOLUME I. Electrical Communication between Lightships and the Coast. (A Brief Description of Bedwell's Patent Mooring Swivel.) Meteorological Phenomena on the East Coast of Africa. Description of the East Coast of Africa from the Mouth of Umba River to Ulenge Island. Sailing Directions for Moa Bay. Sailing Directions for Mansa Bay. The Approach to Para and the Channels of the Amazon. Extracts from the Latest Sailing Directions for Atshin, Sumatra. Petroleum Lights as Aids to Navigation. Some Observations on St. Rosalia, Gulf of California.

Minor Notes: Climate on the S. W. Coast of Africa; Meteorological Journals Received at the German Observatory in December, 1894.

Weather Report of the German Coast for December, 1894.

VOLUME II. Voyage from Apia to Singapore. Survey of the Harbor of Lindi, East Coast of Africa. Test of the Pintsch System of Gas-buoys. Review of the Weather in Germany during 1894. Criticism of V. Kurs' Work on the Navigable Waterways of Germany. Barca Quebrada and Braxilito, Costa Rica.

Minor Notes: Meteorological Journals Received at the German Observatory during January, 1895. Weather Report for January, 1895.

DEUTSCHE HEERES-ZEITUNG.

JANUARY 30. To My Army—Address of Emperor William on the Twenty-fifth Anniversary of the Franco-German War. Pioneer Regulations for the German Infantry. Strategical and Tactical Review of the Battle near Blumenau-Pressburg, July 22, 1866 (continued).

FEBRUARY 2. Mobilization of the Belgian Army. Strategical and Tactical Review, etc. (concluded).

FEBRUARY 6. French Cavalry Reserve and the Required Horses. Report of General Baratieri on the Capture of Cassala.

FEBRUARY 9. Military Service of the German Public School Teacher. Report of General Baratieri, etc. (concluded).

FEBRUARY 13. Naval Vessels Lost in 1894 (A Review).

FEBRUARY 16. Lecture of Emperor William before the German Military Society.

FEBRUARY 20. Wealth in the German Army. Battle Tactics of Infantry Armed with Modern Arms.

FEBRUARY 23. Archduke Albrecht of Austria. Battle Tactics, etc. (continued).

FEBRUARY 27. The Italian Army in Abyssinia. Battle Tactics, etc. (continued).

MARCH 2. Financial Aid to Officers Retiring from the German Army. Battle Tactics, etc. (continued).

MARCH 6. Progress of the German Navy in 1894. (A review of the vessels completed and of those laid down and in progress of construction.) Battle Tactics, etc. (continued).

MARCH 9-13. Battle Tactics, etc. (continued).

MARCH 16. The Armored Cruiser.

A brief description and comparison of the different types of this class of vessels built by the various naval powers, from which the writer considers that of the cruiser New York as the best type.

Battle Tactics, etc. (continued).

MARCH 20. Battle Tactics, etc. (continued).

MILITÄR WOCHENBLATT.

FEBRUARY 2. Armored Cruisers. (An argument in favor of this class of vessels for the German Navy.) The Mobilization of Two French Reserve Cavalry Regiments in October, 1894.

FEBRUARY 20. Pioneer Service of Infantry. A New Field Gun adopted in France.

FEBRUARY 23. Pioneer Service of Infantry (concluded). Contributions to the History of the Years 1847-48 (concluded).

MARCH 6. The Movement of Field Artillery in Battle. The French Army Budget. New Regulations for the Russian Transport Service in War.

MARCH 9. The Movement of Field Artillery in Battle. The Riding School. Madagascar.

MARCH 13. Madagascar (concluded).

MARCH 20. Reorganization of the Italian Army.

MARCH 27. Cavalry Divisions during Peace. Holland's War on the Island of Lambok in 1894.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOLUME XXIII., No. III. Defensive Naval Strategy (The Defense of the Coast), A Study. The Use of Torpedo Nets on Battle-ships. Modern Naval Tactics. The French Battle-ship Brennus. The English Battle-ship Majestic. The English Torpedo-depot Vulcan. Basius' Bateau Rouleur. The English Navy. The English Torpedo-boat Destroyers Boxer and Lynx. The English Sloops Alert and Torch. The German Battle-ship Ersatz Preussen.

This vessel will shortly be laid down at the navy yard, Wilhelmshaven, and it will be an improved Kurfürst Friederich Wilhelm. It will require four years to build her. Harvey armor will be used instead of nickel steel armor. Estimated cost, 20,000,000 marks, of which sum 14,120,000 marks is estimated for the hull and machinery, 5,000,000 marks for the armament and 512,000 marks for the torpedo outfit.

New Common Shell Adopted in the English Navy. Contrivance to Destroy Torpedo Nets. The Use of Aluminum for the Bottom Plating of Ships. Annual Report of the Secretary of the Navy of the United States. Another Plan to Reach the North Pole. Coaling Men-of-War.

Tables giving the rate of coaling from lighters and vessels alongside and when coaling alongside a wharf or mole.

Torpedo-boats for the German Navy.

Four new boats have been recently laid down at Elbing. They will be of the most modern type.

VOLUME IV. The Coast Defense Ships Monarch, Wien, and Budapest of the Austrian Navy.

The first has just been laid down at Pola and the last two at Trieste.

The Bow and Stern of Modern Racing Yachts. The Loss of the Elbe. Foreign Navies in 1894. (A review of the progress made in the various navies during the year.) A Project to Drain the Zuider-See. The Effect of Bilge Keels. The French Battleships Magenta and Hoche. Reconstruction of the Italian Battleship Dandolo. The Russian Armored Cruiser Rjurik. The French Navy. The Monterey. The Necessity of Replacing Wood with some Non-combustible Material in Modern Ships of War.

H. O.

REVIEWERS AND TRANSLATORS.

Lieutenant HUGO OSTERHAUS, U. S. Navy.
Lieutenant J. H. GLENNON, U. S. Navy.
Professor JULES LEROUX.

SPECIAL NOTICE.

NAVAL INSTITUTE PRIZE ESSAY, 1896.

A prize of one hundred dollars, with a gold medal, is offered by the Naval Institute for the best essay presented on any subject pertaining to the naval profession, subject to the following rules:

1. The award for the prize shall be made by the Board of Control, voting by ballot and without knowledge of the names of the competitors.

2. Each competitor to send his essay in a sealed envelope to the Secretary and Treasurer on or before January 1, 1896. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary and Treasurer, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Board.

3. The successful essay to be published in the Proceedings of the Institute: and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Board of Control; and no change shall be made in the text of any competitive essay, published in the Proceedings of the Institute, after it leaves the hands of the Board.

4. Any essay not having received honorable mention, may be published also, at the discretion of the Board of Control, but only with the consent of the author.

5. The essay is limited to fifty (50) printed pages of the Proceedings of the Institute.

6. All essays submitted must be either type-written or copied in a clear and legible hand.

7. The successful competitor will be made a Life Member of the Institute.

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By direction of Board of Control.

J. H. GLENNON,
Lieut., U. S. N., Secretary and Treasurer.

ANNAPOLIS, MD., *January* 1, 1895.

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NOTICE.

Discussion or further discussion by members on any of the articles of this number will be printed in the next issue of the Proceedings. Any such matter should be in the hands of the Secretary by December 10, or as soon thereafter as practicable.

J. H. GLENNON, *Secretary and Treasurer.*

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE

Vol. XXI., No. 3. 1895. Whole No. 75.

HONORABLY MENTIONED.

MOTTO : SIMPLICITY.

SUGGESTIONS FOR INCREASING THE EFFICIENCY OF OUR NEW SHIPS.

By NAVAL CONSTRUCTOR WM. J. BAXTER, U. S. Navy.

The warship of to-day is the most wonderful product of the fertile brain of man; the skill of every art, the theory of every science, and the practice of every trade have contributed to its development, while for its efficient use a special talent of the highest order is necessary. It is an arsenal, a fort, a magazine, a drill ground, a training school, a storehouse, a bank, a workshop, a hotel, a barrack, a hospital, a machine, a church, a prison, a home; but above all it is a unit of sea power, a floating weapon controlled by one man for offense and defense. Like other weapons it should be ready for use at any moment, success depending on skill and bravery alone. Practically, however, this weapon is called upon to perform such numerous and varied functions that it has become a honeycomb structure filled with complicated mechanisms, traversed in all directions by a labyrinth of pipes and shafts, and crowded with scientific appliances and intricate fittings, all of which are liable to such derangement and wear that continual repairs are necessary; and it is subject to sudden and unforeseen mishaps which may happen every time the anchor is weighed. The captain cannot now supervise and direct every part or fitting, he must trust more than ever to the skill of his personnel and the reliability of his matériel: but the latter is so complicated and delicate that a personnel of many specialists is required merely for its efficient care and manipulation in peace. The naval officer is not a scientist and specialist, it is his high privilege to understand and use the developments of science and mechanics which are suitable for his purpose. If the appliances furnished him are so intricate as to require a long and special study of each one, he is apt to be lost in a mass of details and and overlook his larger duty of using these appliances merely as instruments which are to be combined in the best manner to produce the most efficient weapon. The crew are far from being specialists, they do not even understand the use of many of the devices about them, and are ignorant of how to take care of them; yet ignorance or negligence is more quickly fatal now than ever before. Every portion of the warship and her equipment should be adapted to secure efficiency with the men available: the human factor cannot be neglected. Any part which saves weight at the expense of durability, which saves space at the expense of accessibility, or which is automatic at the expense of simplicity, is out of place on this floating weapon; no matter how successful it may be elsewhere. The many ingenious appliances and elaborate fittings which crowd our new ships, though worked out with the greatest care, are a source of weakness if they are unnecessary, or if they are not adapted to the trying conditions of service usage. The more simple and durable the ship and her equipment, the greater will be the efficiency, for the crew can become familiar with the use and care of every appliance, and there will be less liability to derangement in excitement or danger.

Mahan has shown us that good men with poor ships are better than poor men with good ships; it is our duty not only to secure and keep the best men, but to secure the best ships and to train the men in preserving and using them, to follow the service tradition of having the personnel and matériel of each ship superior to any foreign ship of the same rate. This is thoroughly realized by every one in the service ; and in the building, equipping and manning of the new ships there has been universal interest; and naturally there was pressure from all sides to make them superior to their foreign competitors in every quality, for each one is apt to think that the quality to which he had given special attention and study was of particular importance. It is therefore not surprising that simplicity has been lost sight of, and that the trying conditions of service afloat were overlooked in the quiet of shore study.

The best warship is the one which most harmoniously combines armor, armament, speed, handiness, habitability and sea efficiency, and which permits the best use of this combination as a whole by the personnel available. The more limited the purpose of this ship the better will be the combination for the end in view; no one quality, however, can be magnified except at the sacrifice of one or all of the others, the lack of which will surely be felt at some supreme moment. In the commendable desire to secure perfection in every quality, have we not lost sight of the prime importance of securing efficiency in the ship as a weapon; and, in the unrealizable desire to fulfill all conditions, so sacrificed simplicity that this weapon is now so complicated as a whole, and so crowded with delicate equipments, that there is too great a liability of derangement or break down from ignorance or negligence?

The ship's efficiency depends upon the certainty that the essential qualities are available when wanted; if they are obtained by intricate and delicate appliances which function properly only on the proving ground or in the workshop when manipulated by skilled mechanics, there is no certainty that they will be reliable at sea when really needed. In the old ships, officers and crew had that special knowledge which came from long sea experience with familiar equipments, but to-day they spend much of their time in port, and the equipments vary with every ship.

This state of affairs being brought about by the demands of the service, its improvement and remedy lies equally with us; but it can only be brought about by *l'entente cordiale* which sees the necessity of sacrificing some pet scheme in order to secure greater efficiency of the whole ship. It is difficult to overcome the tendency to exaggerate the necessities of the present moment, and thus forget the possible contingencies and catastrophes of the future. It can only be done by bearing in mind that simplicity requires that everything should be discarded which is not necessary to the efficiency of the weapon or to one of its essential parts, and that nothing should be added unless the advantages of its presence more than counterbalance the disadvantages of its absence.

We are all too apt to believe that while great reforms are necessary in another's arrangements, our own need only some slight additions to make them perfect. Yet, if all the suggestions were summed up, it would appear that complication and crowding were absolutely necessary; that the ships of to-morrow must be even more complicated than those of to-day; that perfection will only be obtained when a vessel shall be produced which shall contain all known means of offense and defense and all known appliances for economy, comfort and convenience. The followers of this school doubtless believe that in time the warship should be like the popular slot machines, when the captain automatically presses a button the vessel will do the rest; do they ever consider what will happen if the button fails to work?

The sciences of peace should not overshadow the science of war, on the warship.

This is not said in a reactionary or conservative spirit, nor to proclaim the failure of what has been done, nor to criticize in any way the faithful work of those thoughtful officers whose combined ingenuity and study have produced the ships of which we are so proud; but it is no reflection on any one to say that there is still room for improvement.

The writer is convinced of the immense importance of simplicity, and he believes that, without any reduction of the fighting power, or any lessening of those comforts which are necessary for the health and cheerfulness of officers and men, more efficient ships will result from the adoption of simplicity as the ruling principle of design and organization. There is nothing novel in this idea, and numerous authorities could be quoted; the following, however, expresses the thought very clearly.

Jurien de la Gravière says: "Les idées simples ont toujours quelque peine à prevaloir. Quand l'heure critique arrive, c'est infailliblement à elles qu'on a recours. Le pédantisme technique ne resiste pas à quelque jours de campagne."

Hichborn says: "The warship of our day has become far too complicated for the people who may be called upon to work her;

a balance of advantage, unsuspected by many, rests with that vessel which has comparative simplicity."

Simplicity does not mean an entire return to manual power, although the time will never come for its abandonment; it does not mean that every mechanism or appliance should be so simple as to be used or cared for by the merest landsman; nor does it imply that the fittings which increase safety and health should be discarded. But when for any safeguard supplied, another is crowded out or rendered useless; when one appliance must be accompanied by others to provide for the possibility of a break-down; when the hull requires such constant attention for its care and preservation that there is but little time for drill; when the motive machinery has the delicacy of a watch; when the decks are crowded with encumbrances of all kinds which obstruct the use of the battery and its supply of ammunition, or which render the crew uncomfortable and discontented; when the crew is composed mainly of specialists who know little else than their own particular duties;—when all this is the case, is it not time to remember that the warships exist only to carry guns, and that the officers and crew exist merely to fight them?

Our service is particularly fortunate in combining within itself those qualities which produce improvement; it is renowned for its knowledge of mechanical contrivances, and it has avoided the error of embodying all knowledge in one class of officers and all experience in another. Mere knowledge is insufficient; experience is absolutely necessary to produce the best results, as it gives insight into the causes of failures. Many fittings look well on paper, and even function well in the hands of their builders, which fail when used by those who have not the specialized skill required for their manipulation; and it often occurs that appliances which are satisfactory on shore are found to be entirely unsuited to service conditions afloat. In the difference between the grumbling statement of one officer that a certain part of the ship's equipment is "no good," and the intelligent report of another which states the circumstances of the failure, the probable reasons, and suggests a remedy, lies the key-note of successful improvement; one is mere experience, but the other combines knowledge with experience.

The happy union of these two qualities is especially desirable when considering the value of a ship as a weapon. Invention should receive constant encouragement, but the inventive faculty, unless guided by experience, may run riot and produce a chaotic jumble which shall be defective as a whole, even though there may be no marked defect in any particular fitting. The electric light, the bicycle and the sewing machine are familiar examples of improvement brought about by simplification; those parts which are unreliable, or superfluous, are altered or discarded, and the result obtained by other means in a more satisfactory manner, after close study of the actual conditions of service. The warship of to-day is a new invention, for each one is a new combination of many inventions, and it can be improved in utility and reliability only by the combined efforts of those who build it and those who use it.

Familiarity with the behavior and performance of the ship under all conditions is the best way to ascertain the defects and their causes; and experience in remedying many defects of the same nature, developed under different conditions, is the best way to determine upon the improvement which will be most efficient in all cases.

At the close of the Civil War naval personnel and matériel were extraordinarily efficient because activity and invention were stimulated by necessity, and restrained by knowledge of the actual conditions of war service. The lack of any extended knowledge of naval warfare with modern warships emphasizes the importance of continual practice under conditions resembling those of war, to discover the good and bad qualities of each ship, so as to manœuvre and fight her to the best advantage in action, as well as to determine the best solution of the many problems still unfathomed for lack of experience. War efficiency is of the highest importance, but it is also essential to check unnecessary and wasteful expenditure, and to promote economical administration. The first cost of mere peace fittings is very great, and the expense of their repair often exceeds that of the essential fittings. They are also hurtful in their effect on the ship's discipline, as the crew become accustomed to refinements and conveniences which must be lacking in active service, and a spirit of fastidiousness in unimportant details is developed which exaggerates their importance, and fosters the habit of thinking that the ship is not ready for sea merely because some minor fitting is incomplete or unsatisfactory. While it is necessary that every part of the ship's equipment should be so perfect that there will be small chance of derangement when it receives reasonable care, and so simple that the repairs due to ordinary wear and tear can be made by the ship's force; it is equally necessary to cultivate a spirit of responsibility and self-reliance, and a desire to remedy the innumerable small defects which are sure to occur, without the aid of a navy yard. If the crew do not feel the responsibility of making good all ordinary defects, due to service use or to casualties, a spirit of recklessness quickly appears, the ship becomes less efficient and the money paid for such repairs is an inexcusable waste. It is of still greater moment to prevent this, because preparation for battle in the most speedy and precise manner is a requisite for success; if the crew is so helpless as to depend on outside help in the most trifling matters, what can be expected in the hurry and excitement of such a time? Even when the crew is skilful and well trained, the time required for repairs must be taken from that belonging to drill or recreation, so that there is every reason for omitting all unnecessary fittings.

Mahan says: "Theories about the naval warfare of the future are almost wholly presumptive." But he also says, in speaking of England's policy in the Napoleonic wars: "She obtained the double advantage of keeping the enemy under her eyes, and of sapping his efficiency by the easy life of port, while her own officers and seamen were hardened by the vigorous cruising into a perfect readiness for every call upon their energies." We do know, however, that the war of the future will come unexpectedly, and that unless the ships are efficient and the crews are familiar with the means of offense and defense they contain, the ablest strategy and the most brilliant tactics will be of no avail. In view of the lack of both money and men, it will doubtless be necessary when all of the new ships are completed, to establish a class of ships in reserve which shall contain the mere nucleus of a crew, and as many small ships will be required for detached service and duty on foreign stations, this reserve will naturally be composed mainly of battleships, coast defense vessels and the larger cruisers. When mobilization for war service becomes necessary, these ships will be needed at once and the few men who know the ship will be lost amidst new recruits. In such emergencies, the ships will be manned mainly by those accustomed to merchant ships and those who have had no experience afloat, and it will be fortunate if the great guns and main engines are used without casualties. We have only to read the accounts of foreign naval manœuvres to be impressed with the many casualties happening to machinery, boilers and steering gear and the numberless break-downs of minor appliances. When such things can happen in times of peace with other navies having a large number of trained men in reserve, and with sufficient warning to navy yard authorities to ensure the matériel being in fair condition, what can we expect with our limited navy yard facilities and the entire absence of any trained seamen? We have the volunteer Naval Reserve whose bravery and ability are unquestioned, but their experience cannot be sufficient to enable them immediately to manage the complicated mechanism of our new battleships. Hollis says: "At present it takes from six month to a year after a new ship goes into commission to get the best results out of her machinery; and through no fault of the firemen. It is only that they do not know when first taken on board." When this is the case is not some simplification necessary?

The necessity for rapid mobilization is but one of the many arguments in favor of simplicity, especially on large vessels. The captain manœuvring such a ship in action can no longer inspire the crew by his presence, he will not even know a tithe of what is occurring in the complicated structure he is directing, and even if he did he could not be certain that his orders were correctly understood and promptly obeyed. More than ever before will the issue depend on the nerve, judgment, and skill of the captain, and on the training, discipline and staunchness of the crew. Cannot a greater efficiency be obtained by making the ships less complicated, so that when the unfortunate necessity arises of fitting them out in haste, the essentials can be quickly mastered, and the crew can feel that, although they may be exposed to more danger from the enemy, there is less probability of danger from some act of ignorance or negligence of their own? The question of manning must be recognized.

In times of ease and leisure, elaborate and complicated methods of the completest character are a fascinating study, but in times of action and pressure the simplest methods will be used. If the battleship cannot be made invulnerable and unsinkable except by intricate and delicate means which may fail in the hour of trial, it is surely better to secure simpler and more reliable means of offense and defense, and accept the risks ensuing from the absence of complicated refinements; or, to use Farragut's words, "The best protection against the enemy's fire is a well directed fire from our own guns."

One other reason for simplification: many methods for evaluating the fighting powers of warships in comparison with others of the same tonnage have been proposed, but as their different authors assign different relative values to each element of offense and defense, it is not to be expected that there will be agreement. The actual values of each element, however, tend to equalize themselves more and more; in guns, armor, machinery, torpedoes, subdivision and the like, the knowledge of what each navy is doing is so accurate, and the competition is so keen, that it is probable that real superiority of matériel will lie in simplification of detail. Between two ships equal in all other respects, the one which has the more simple matériel will be the more efficient, because it is not so easily or quickly deranged, and therefore the crew of that ship will have more confidence in her performance; their courage will be increased by knowledge of every resource, and many daring and unthought of expedients can be used with success.

Soley says: "The primary object for a navy at all times is to maintain itself in all its branches, matériel, personnel and organization in the most perfect state that is possible of readiness and efficiency for war." When any one feels that a greater degree of readiness and efficiency is possible, it is his duty to point out apparent defects and to suggest some remedy, leaving to higher authority the determination of the merit and practicability of his ideas. Every innovation is followed by unexpected consequences, and many objections can be raised against every suggestion offered; but when the service shall see that the defects due to complication have arisen from its own demands for perfection in every direction, further departures from simplicity and economy will cease. It matters little who furnishes suggestions for each improvement in the future, so long as there is a concensus of opinion as to their desirability.

In such a paper as this the treatment of the many branches of the subject must necessarily be sketchy and incomplete.

Standardizing is the most obvious means of securing simplicity. When the use and care of standard appliances and fittings are once learned, there will be less loss of efficiency when officers and men are transferred from ship to ship, and on foreign stations extensive repairs can be made by making good the defective parts of one ship from the surplus stores of another.

Standardizing reached its highest perfection at the opening of the century, when ships of the same rate were practically alike from keel to truck. During the long cruises of that period the crews became so familiar with every part of the equipment, that its use and care became almost an instinct. Extraordinary results were accomplished: the marvelous repairs to the Vanguard, and the skill displayed by the new crew of the Constitution, are familiar examples.

Conditions are now different, for the rapid progress of naval science quickly renders obsolete the fittings which were thought to be satisfactory. Too much uniformity will result in mere routine and discourage invention, but standardizing could safely be carried further than has been done. The lack of uniformity is largely due to the many rival ideas among ourselves, but this can be obviated by deciding on the fitting that is best suited for a particular purpose, and then continuing its use, even if it prove deficient in some respects until it becomes clearly obsolete. We have now had sufficient experience with the new vessels to extend the standardizing so admirably begun with ordnance and electrical fittings to many other parts of the ship's equipment.

The question of design is too large for consideration; but it is worthy of note that all navies have strayed too far from simplicity in one respect. In the effort to satisfy all demands and combine on small ships high speed, powerful armament and great protection, there has been such a great sacrifice of strength, stability, habitability and coal endurance, that efficiency as a whole has been lessened. To combine all these qualities in the best manner, there is no longer any doubt that large and costly ships are required: with small ships, some qualities are now deliberately sacrificed to secure reliability in others, as the necessity for simplicity is better understood.

Subdivision is a necessary departure from simplicity, its function being to prevent or delay capsizing or foundering; practically its value is vitiated by the necessity for piercing water-tight bulkheads and decks with doors and other openings, and pipes of all kinds. The Admiralty minute concerning the loss of the Victoria states that had the water-tight doors and hatches been closed, the ship would have been saved, but unfortunately it took from three to four minutes at the best to close them and the signal to do so was not given until one minute before the collision. The foundering of so many Chinese ships was probably largely due to the failure to close the doors by crews not properly trained. The difficulty of communication between the various parts of the ship and the great inconvenience ensuing when the doors are closed causes both officers and men to prefer the risk of foundering to the remedy. A certain number of doors must be kept open in action or fleet manœuvres, for the supply of ammunition and the control of the ship; but this is a necessary risk, which is minimized with a crew well trained to close them in an emergency. The danger lies with doors supplied for convenience and accessibility; even though they be reported closed, there is no surety for their remaining so during a panic. Simplicity demands that their number should be the smallest possible consistent with efficiency, at the sacrifice of convenience. Although it may be practicable to keep a greater number in good condition, more men and greater time are required to close them.

The advantages of subdivision, and the effect of flooding different compartments are not thoroughly understood throughout the service, and it would be of great benefit to establish a "stability school", which would afford a short, but instructive course showing by means of suitable models the alterations in stability and in trim occurring in different vessels from flooding compartments singly and in communication through open doors or injured bulkheads. Information presented in this manner would be of greater practicable value than in the shape of technical formulæ and curves.

The weight of opinion now seems in favor of an even greater subdivision in the vicinity of the water-line, with fewer bulkheads elsewhere, to reduce the liability of capsizing at the expense of some floating power; the usefulness of a ship, when floating keel up, being questionable. It may be said that bulkheads above the water-line will quickly be rendered useless by the enemy's rapid-fire guns, and therefore, by my own reasoning, there is no use in further complicating the ship; but this is a case when the gain from complication is greater than the loss, as a delay of even five minutes in sinking, may save the lives of the greater part of the crew. Subdivision is the best expedient for reducing the chances of serious accident.

In protective decks there has been a lamentable departure from simplicity; in securing efficiency of minor details, the efficiency of the ship as a whole has been lessened as the decks are pierced in every direction by pipes of all sizes. Some of these, it is true, are provided with automatic valves of uncertain action, but the greater number are only closed by valves located below this deck. When it is struck by a projectile in their vicinity the consequence is obvious, and there is a great probability of stray shots from rapid-fire guns finding some of the many unprotected openings penetrating below the deck and causing fatal damage. The reports of the Yalu fight state that the pumps of all the ships engaged were working furiously, and it seems probable that even on the ships which did not sink, there was much alarm from these causes.

There is no use in weighting down the ship with such an encumbrance unless it be made efficient; no openings should be permitted except those which can be closed in action at short notice, or which must necessarily be open at all times for the working of the ship, and whose risk is known and accepted. Coaling scuttles and ammunition hatches can be closed by water-tight shutters, but all other openings should be concentrated near the machinery space and protected as far as practicable. This can be done by a simplification of piping, by placing dynamo and pump rooms amidships as described later, and by separating the ventilation of living quarters entirely from that of ammunition and store rooms, the inlets and outlets of air for the latter being at the extremities of the machinery space.

Rapidity in coaling ship and in supplying coal to the fire rooms is of vital importance, and continually occupies the thoughts of many able officers. It may not be out of place to mention that the difficulties will be lessened by the various simplifications advocated by the writer on other pages, for they would enable the lower bunkers to be made of greater capacity, even on the smaller cruisers. Such bunkers can be more easily and quickly stowed; the scuttles in the protective deck can be kept closed in action because there will be sufficient coal below for continuous rapid supply; and with equal weights of coal less space will be required on the berth deck. This is but one example among many, which shows that when any portion of the ship is simplified there are many resultant benefits.

The man is the most important part of the ship's mechanism; but how has he been treated? Compare the San Francisco with the Constellation, the Detroit with the Portsmouth: the proportion of officers to crew has certainly not been diminished, yet the comforts of the officers have been increased while those of the men have been lessened. At night, even in port, they are packed in small compartments, heated by fire rooms and dynamo rooms or steam pipes wet from condensation or leaking pipes, and at sea their condition is even worse. To offset these discomforts, there have been supplied lockers of all kinds, bake ovens, steam cookers, refrigerating machines, and many other conveniences, but in the small space assigned him, Jacky cannot find rest day or night. The service of guns, the care of ship and machinery and their many complicated appliances require a constant vigilance which cannot be had unless the men can rest when off duty; tickling their palates with hot rolls and ice water is not sufficient. Every one having experience on the new ships feels the necessity for larger crews in war, the present complements being inadequate to perform the many responsible and onerous duties required to secure anything like continuous efficiency; they can stand the pressure during a few hours of excitement, but the continued strain of watching and waiting for the enemy must be distributed among more men, in order that everything shall be ready when he appears. Simplification is thus needed in two directions: a reduction in the number of appliances requiring constant attention, so that fewer additional men will be required; and an increase of crew space by curtailing as far as practicable the space now occupied for other purposes.

The space assigned to officers' quarters in the earlier cruisers was large in order to carry more officers than were required for purely military purposes so that the greatest number possible might obtain sea experience under the altered conditions of modern ships; but as ships become more numerous, fewer officers will be assigned to them, and some of the space now occupied by their quarters can be given to the crew. The innumerable returns, accounts, invoices and other papers now deemed necessary, not only absorb much time from officers and men in mere clerical duties at the expense of true efficiency, but require a large proportion of space in their preparation. With the present rage for scientific investigation and reports, one is tempted to believe that, in a few years, the captain of the hold will have a berth deck office and submit a daily report of the chemical analysis of the contents of his water tanks, a weekly report of the amounts consumed for the various purposes of ship economy, and a quarterly report giving the effect on ship and crew of the varying qualities and quantities of water used; all of which would give very valuable scientific information no doubt, but its collection would be entirely out of place on a warship.

Not satisfied with the crowded state of the ship when newly built, no sooner is she in commission than the demands for more fittings, comforts and conveniences become unceasing; another locker, a book case, a desk, a broiler, a deck gear room and the like, are called for and the crew space is lessened continuously: even when additional crew space is obtained by one officer, others promptly ask for additional encumbrances to occupy it. There is no doubt that in time of war both officers and men would demand a general clearing out from stem to stern of everything that was superfluous or merely convenient; but why not simplify now? During visits to navy yards, if all would join in putting obstructions on shore instead of taking more on board, the gain in efficiency would be very great. It is not necessary in peace that the ship should have the Spartan simplicity of war; on the contrary, let us have every comfort that will add to health and cheerfulness, which does not militate against the efficiency of the ship as a weapon; but if common sense does not rule in their selection, we merely crowd the ship with useless gear liable to get out of order.

The Yalu fight has awakened the service to necessity for abolishing wooden bulkheads and elaborate joiner work, to minimize the danger from fire and flying splinters; but it is worthy of note that Nelson, after his experience at Aboukir, considered fire as the greatest danger of naval warfare.

Although the boiler is the most important piece of mechanism on the warship, there has not been so much progress in adapting it to the conditions of modern warfare as has been the case with other parts of the equipment, until during the last few years. The space occupied by cylindrical boilers is nearly two-thirds of that occupied by the whole propelling mechanism, and their weight is more than one-half the total machinery weight, for their form is least adapted to close stowage and reduction of weight. Tubulous boilers are less liable to derangement from accident or neglect they occupying less space, for they can be stowed to better advantage; they are lighter, and steam of higher pressure can be raised in much less time; faults can be sooner detected and easier repaired; but it is only fair to state that their opponents claim that many of these advantages are illusory or are gained at the sacrifice of more important qualities. Many objections of the same nature were offered when surface condensers first appeared, but are heard no more. Efficient boilers should be able to steam quickly and safely at full power at any time during a cruise; other considerations are secondary; but all requirements are met by the tubulous boiler, and its general adoption seems certain.

In the advance from simple self-contained engines to the triple or quadruple-expansion engines of to-day there has been a development of increased power with lessened space and weight beyond the most sanguine expectations of even ten years ago. The Boston and Cincinnati are of practically the same size, yet when the former has one engine the latter has two which develop more than twice the power on the same weight. The complexity necessary to accomplish this is no departure from efficiency when the engines are strong, reliable and durable, for they are directly under the observation of officers who possess skill and judgment to operate and preserve them; and any unusual wear or uncertainty, any fault or weakness can be quickly detected because they are continually in sight. Standardizing has been carried out to a large extent, and there has been much simplification; the Wabash valves of early days have disappeared, and the radial valve gears of geometrical perfection are being displaced by the old familiar and reliable link motion.

In another direction, however, a great departure from simplicity and efficiency has occurred. The auxiliaries necessary for the functioning of the propelling machinery are no longer attached to the main engines. They are now independent and scattered throughout the whole machinery space, where they cannot receive the watchful and responsible supervision necessary for their efficient performance; break-downs occur and it is necessary to fit additional auxiliaries to provide for such emergencies. It has been stated that the speed endurance depends as largely on the propelling auxiliaries, as the fighting power depends upon the secondary battery. A stronger case could easily be made out for them, but it is the number of auxiliaries which is being discussed and not their duties.

There are many auxiliaries outside of those connected with the propelling machinery, and the following table has been prepared from the best information at hand to show their number and uses on various types of ships; the classification explains itself.

INDEPENDENT STEAM AUXILIARIES ON VARIOUS SHIPS.

NAME AND USE.	NUMBER.						
	Indiana.	New York.	Minneapolis.	Cincinnati.	Detroit.	Lancaster.	Alliance.
Propelling Service.							
Main air pumps	2	4	3	2	2		
Main circulating pumps	2	4	6	2	2		
Engine water-service pumps	2	2	3	2			
Reversing engines	2	4	3	2	2		
Turning engines	2	2	3	1	1		
Boiler Service.							
Feed pumps	12	10	12	8	6	1	
Forced draught blowers	10	14	16	6	6	2	2
Ship Service.							
Capstan	1	1	1	1	1	1	1
Steering engine	1	1	1	1	1		
Ventilating blowers	6	6	8	4	4	2	
Fire, feed and bilge pumps	2	4	3	2	2	2	3
Fire and bilge pumps	2	2	3	2	2	1	
Evaporator and distiller pumps	6	4	3	3	3	1	1
Auxiliary air and circulating pumps	2	2	2	3	2		
Workshop engine	1	1	1	1	1		
Wrecking pump		2	1				
Military Service.							
Turret turning	6	2					
Hydraulic pumps	2						
Ammunition hoists	4	2	4				
Air compressors	2	1	1	1	1		
Dynamo engines	3	3	3	2	2		
Handy Service.							
Ice machine	1	1	1	1			
Winches	4	6	2	1	1		
Ash hoists	4	6	8	6	6	1	1
Number of independent auxilaries	79	84	84	51	45	11	8
Number of independent water pumps	26	24	25	17	13	5	4
Number of main engines	2	4	3	2	2	1	1
Number of boilers	6	8	10	6	5	4	4
Displacement	10,288	8200	7375	3213	2094	3250	1375
Complement	424	526	456	292	254	338	157

Economy in coal expenditure is of vital importance: in peace from financial reasons, to save money; and in war from military reasons, to save time. Coal is as necessary for speed to secure the weather gage as are the great guns when once the fight is on. Every unnecessary mechanism should therefore be discarded.

It is proposed by some to produce great coal economy by paying more attention to the design of the auxiliaries and make each one as perfect as possible; but this involves more complication and more skillful attention, so that there will be even greater probability of break-downs than is the case now. This solution of the problem is directly opposed to the principles advocated in this paper.

Others again propose to let the auxiliaries alone and devote greater attention to increasing the economy of the main engines, arguing that increased delicacy and complication are practicable with the skilled supervision and attendance they receive: but it is impossible to obtain economy with the main engines at all the various ranges of power required by the warship, and a choice must be made as to when economy is most desirable. In any case, it can only be obtained by increasing both complication and weight beyond what is necessary or desirable. Reliability is of more importance than economy, and the best and most simple plan seems to be to secure greater power with a given weight of coal by using steam of higher pressures, and by reducing the number of auxiliaries.

Some of these auxiliaries are merely handy labor-saving devices, and are not absolutely necessary. Six ash hoist engines are surely not required on a 3000-ton ship; in many cases their work can be performed to advantage by the deck force who are often not sufficiently employed when the ship is under way, when they cannot be spared from other duties; two ash hoists would be sufficient if suitably placed, as by the aid of leading blocks the refuse of each fire-room could be hoisted through its own ash chute; on smaller ships this could be done by the boat winch. The loss from condensation in exposed lines of piping and from wasteful engines would be prevented, and there would be fewer repairs needed.

The ice machine and permanent refrigerators are luxuries which may be permissible on large ships where the space occupied and the coal expended is but a small proportion of the total available for other purposes. On small ships, however, the additional comfort they provide for a short time are obtained by a sacrifice of space and a waste of coal which detract from real efficiency.

The number of independent auxiliaries will naturally increase with the size of the ship; their relative cost in coal, weight and space will not be so great, and as the complement does not increase in the same ratio as the displacement, the presence of more and larger guns or boats requires something besides manual power for their rapid manipulation. On the other hand, the larger ship requires more care and attention from the crew simply because it is larger; so that there is no reason why unnecessary auxiliaries should be placed on ships for the mere reason that there is space for them. In general, the ruling principle should be to discard every auxiliary whose functions can be performed by manual power without reducing the fighting efficiency, to reduce the number required for emergency or convenience to the lowest possible limit, and to design such as cannot be dispensed with so that they shall be simple, strong and reliable, with one engine performing several duties when practicable.

The great number of pumps supplied the new ships is especially noticeable. Concerning the speed trial of the Minneapolis, it is stated: "The water in the glass gauges was perfectly steady, and only half the feed pumps (at the moderate speed of thirty-one double strokes per minute) were required to keep up the supply." An emergency provision of 100 per cent. above the maximum requirements appears extravagant, to say the least. The numerous feed pumps, fire pumps and bilge pumps are doubtless due to an exaggerated appreciation of the truth that duplication gives safety, while the equally important truth that concentration gives security is overlooked. The ship's armament is dispersed to reduce the chances of its being disabled by a few well aimed or lucky shots, and the large fighting crew is intentionally scattered for the same reason and to have a reserve available to make good inevitable losses. The motive power, on the contrary, should be concentrated because it must be under perfect control to be useful; it must be protected to the greatest practicable extent; and the smallest number of men, consistent with efficiency, should be concentrated at this duty. Some emergency pumps are essential, but if the main pumps are well designed and reliable, and receive greater care, fewer emergency pumps will be needed. If all the pumps necessary for boiler supply, drainage, fire and flushing service were situated in a pump room located amidships and below the protective deck, they would receive better supervision and care with fewer attendants, a smaller number would be necessary, and their concentration would greatly reduce the present maze of piping. Instead of pumps in the fire rooms which require unceasing vigilance to counteract the evil effects of ashes and coal dust, the pump room would provide a continuous supply of feed water, and more attention could be paid to firing; while the removal of the other pumps from the engine rooms would enable the attendants there to devote all of their time to the motive machinery; fire rooms and engine rooms would be less crowded and the lower bunkers could be made larger.

The numerous steam auxiliaries all over the ship necessitate many steam pipes passing through berthing spaces and store rooms where heat and leaky joints are very objectionable. Aside from this, the terrible possibilities of even a small pipe bursting from the casualties of action are a sufficient justification for abolishing steam auxiliaries outside the machine space, where possible, even if they be replaced by others more wasteful of coal, provided the ship's efficiency, as a weapon, be increased. The hydraulic pipe and the electric wire can be led to the various necessary auxiliaries with greater ease, they occupy less space, cause less discomfort by their presence, and above all, will cause no serious disaster if ruptured. The steam engine, especially when used intermittently, requires some skill to start it; whereas the hydraulic or electric motor can be used with safety and precision at any time, after the most elementary training, as is shown by the character of the operators of the familiar elevator or trolley car. Although such motors require a high degree of skill and intelligence for their repair, a fewer number of specialists is required, and the great amount of standardizing permits casualties to be quickly repaired at short notice; they also have the advantage of being easier kept in good condition as there is less difficulty from corrosion. Their use for capstans and steering engines, however, is clearly undesirable at present; fortunately, steam pipes for these auxiliaries can be arranged to obviate many of the objections mentioned.

The use of some motive power other than steam necessitates the use of additional appliances for their creation, and any conversion of power involves some waste of coal. It may therefore be thought that the plea for such motors is contradicted by the reasons given in advocating simplicity and economy. This is true; but such motors are advantageous from a larger view of real efficiency, and the departure from simplicity and economy is not so great as might appear at first sight.

It is not wasteful of coal when a new weapon like the torpedo, a new safeguard like the electric light, or a marked increase in health and comfort are the result. Power is transmitted to such motors with but little loss even through flooded compartments; but there is a great loss from condensation in long lines of steam pipes, and steam power cannot be transmitted at all through flooded compartments.

A discussion of the relative merits of electric, pneumatic, and hydraulic motors is out of place; it is sufficient to say that the development of applied electricity on the warship is rapidly increasing, now that its possibilities and limitations are better understood, and its advantages for military purposes are appreciated. Its use for search lights and signals, ammunition hoists, gun mounts, turret turning, range finders, firing circuits and the like is well established, while for lighting and ventilation it is invaluable.

Successful electric counters, telegraphs and indicators are the ideal appliances for these purposes. There should be many places about the ship where the captain can direct the ship, and although the present mechanical appliances are generally reliable, they are cumbersome, and it is impracticable to scatter them owing to the practicable difficulties in getting proper leads. The electrical appliances thus far provided, are unreliable, but with their development will come efficiency.

Voice pipes are cumbersome, are a source of danger, and are unreliable, because confusion may arise from orders imperfectly understood, as the central station is better in theory than in practice. What a gain there will be when a suitable telephone shall be developed which will enable the conning tower to distinctly transmit orders to all parts of a ship!

In electricity, as in everything else, we shall stray from efficiency unless simplicity and economy be borne in mind. Such toys as automatic electrical whistles, automatic steering compasses and similar fittings are unnecessary and should be discarded. The electric light is so convenient that the temptation is very great to lose sight of economy in the installation and use of lamps. Fixed lights are located in storerooms and other places where portables could be used; and officers are very apt to use the electric lights on trivial occasions where hand lanterns would answer, or to consider the lamps in their own quarters as a necessity instead of a luxury;—how many stop to think that it takes 2 pounds of coal per hour for a sixteen-candle-power lamp?

To complete the concentration of the principal auxiliaries within the machinery space, the dynamo room should also be located amidships and below the protective deck in a separate compartment; a better and more economical system of wiring would be possible, an easier and safer generation of electricity due to better ventilation and dryer steam; the dynamos would be better protected, and the crew would be saved much annoyance and discomfort.

The maze of piping on the warship of to-day is fully appreciated only after experience on bilge boards. Pipes are found everywhere, encumbering the double bottom, hiding the inner bottom, and obstructing coal bunkers, berthing spaces and officers' quarters. It is no exaggeration to say that their total length exceeds that of the standing and running rigging of sailing ships of equal size, and that the number of valves is greater than the number of blocks. It is claimed that the presence of all these pipes and valves is as necessary to the warship of to-day as the rigging and blocks on the ships of 1812, and that there will be a loss of efficiency if they are reduced in number and simplified. This parallel is not a happy one, for the rigging was reduced in amount and was simplified whenever necessary by furling sail or by sending down yards and spars; the pipes, on the contrary, must always remain as fitted. The rigging was always *en evidence* its weakness could be detected before injury was done, and its defective parts could be quickly repaired or replaced by the crew, with the stores and appliances on board; but the piping is generally hidden from view by floor plates, stores and lagging, and its interior is never seen; its weakness develops gradually and can rarely be detected until a break-down occurs, which, usually, can only be temporarily repaired by the crew, as it is impossible for them to replace any except the smallest-sized pipes.

Again, the location and use of every part of the rigging were so familiar to every man on board, that on the darkest nights, or in sudden emergencies a mistake was extremely rare; and when a mistake did occur, it quickly betrayed itself and could usually be quickly remedied. What a contrast with the warship of to-day: how many officers and men are there who know the names and uses of every pipe they see, how many men know the leads and combinations necessary to flood this compartment or to pump out that one, if the routine gear is out of order? When it is not uncommon to find that water has entered the double bottom from negligence or ignorance, how great must be the danger in the excitement of action if this can occur in the daily routine of peace? What can be done to simplify? Some suggestion concerning steam and ventilation pipes are offered elsewhere. With drain pipes, there has been a tendency towards requiring that every compartment should be emptied by every pump, but experience with the labyrinth of pipes and fittings already fitted has shown that many of them are rarely utilized. It is desirable, no doubt, to have the drainage complete; but it is more desirable that this should be done in such a simple and reliable way that every petty officer can learn to manipulate the system and thus eliminate the danger arising from entire dependence on specialists to operate the multitude of valves, when blunders may imperil the safety of the ship.

The many small pumps required for the fresh water service are a fruitful source of annoyance, but the growing system of having one pump fill a cistern located in or above the hammock berthing, from which the water is distributed throughout the ship by gravity alone, is exactly in the line of progress advocated. Those who have had experience in breaking out a lower bunker on the eve of sailing to get at a leaky joint, may think that an effort should be made to standardize the leads of pipes; but if joints are located in accessible places, and if the pipes do not pierce the protective deck outside the machinery space, further simplification will not be necessary.

Brassey says: "Nowhere more than in the forces of the navy and the army do we see indications of that thoughtless impatience to be in the new fashion of the day. Should it not be remembered that an instrument of war depends for its value not only on the weapon itself, but on the training and knowledge of those in whose hands it is placed?" Officers naturally desire to have everything of the latest and best type regardless of the cost, when greater efficiency can be secured. Yet true economy is but another term for efficiency, and when the service realizes the immense improvement which a well developed system of economy will bring about, gratifying results will follow. This does not mean that fighting power should be subordinated to a parsimonious use of stores, or to a niggardly policy of repairs, for that is false economy; it does mean, however, that extravagant and wasteful expenditure is an evidence of incompetence or carelessness.

With our form of government, it is not easy to secure money for any purely military purpose unless its necessity is self-apparent. Although it has been realized that high class ships are needed and that high prices must be paid for them; we cannot expect large annual appropriations for the maintenance and improvement of these ships unless it be self-evident that carelessness and extravagance do not exist, and that the necessity for economy is appreciated. It is imperative that excellence be secured by economy, for if there is carelessness or waste, a disastrous reaction will set in, and the navy will again suffer as it did twenty years ago.

First cost is always important; but when a greater expenditure will secure greater fighting power, or will secure greater economy in peace without lessening the war efficiency, there is no extravagance.

Economy in running expenses is essential. These are of two kinds: military expenses, for ammunition, coal, stores, pay, etc., which are regulated by the exigencies of the service and by the policy of the day; and mechanical expenses, for repairs or improvements, which are more or less regulated by the service itself, for they depend upon the ship's design and workmanship and upon the crew's skill and vigilance. The expense of repairs due to wear and tear and to accidents is one criterion of a ship's efficiency, because their amount can be lessened by vigilance and the proverbial "stitch in time;" and as the money available is limited in amount, the less there is required for these expenses the greater the amount available for improvements. Officers whose intelligence and fertility of resource secure economy in peace by maintaining efficiency with the means at hand, will not only add to their reputations but will be developing those qualities which will prove most valuable in war.

Jurien de la Gravière, in speaking of Nelson's long watch off Toulon for the French fleet, says: "Chose digne de remarque! le bouillant amiral managait ses vergues et ses voiles dans les circonstances ordinaires plus soigneusement que son escadre ou son vaisseau dans les occasions décisives." The necessity for constant supervision and attention to detail is more important on the complicated warship of 1895 than on its predecessor of ninety years ago; greater and increasing responsibilities therefore rest on the personnel of to-day as compared with that of the past. Competition is keener and increasing; each new ship is somewhat better than the one before it, and it rests largely with the most intelligent use of the matériel to gain the advantage. No matter how simple and perfect the mechanism, the mere fact that it is a mechanism requires skill and vigilance for its care and management.

Seamanship is the art of providing, preserving and handling ships and their equipment; and the knowledge of this art is more difficult to acquire than ever before because of the many different types of ships, which have their special purposes and peculiarities. With the general principles of this art all officers are familiar, and it is merely a question of time to successfully adapt them to the peculiarities of individual ships; but this time must be taken from other duties, officers are so overwhelmed by a mass of petty details, that a considerable period must elapse before they can grasp the peculiarities of her equipment and summarize her qualities so as to be prepared for the contingencies of service afloat.

This period could be greatly shortened by a study of a "ship's manual" which would contain the results of the investigations of all those connected with her building and equipment, and the results of the experience of those previously serving on her. Such a manual should state, briefly but clearly, the ship's merits and demerits, laying stress on those duties which she is best and least qualified to perform; with descriptions of the armament, ammunition and armor; of the machinery, with statements of the speed, horse-power, and coal endurance under various conditions; of the electric plant, with explanations of peculiar appliances; of the hull and its subdivisions; of the drainage system, and the method of pumping or flooding various compartments and a statement of the ship's trim and behavior when the large compartments are filled. It would also describe the handiness and qualities during all weathers, and mention the parts of her equipment which are most liable to give trouble. In other words, the ship's manual would contain in a concise form that information which every officer gathers and assimilates as best he may, and it would be of the greatest value in rapid mobilization of ships in the reserve.

The drudgery of bilge board duty becomes very wearisome, but in no other way can the ship be known so well and thoroughly. When an officer is able to mentally photograph the interior of every compartment with every important fitting in it, he is far better equipped for handling the ship, and for quickly deciding what should be done in an emergency, than one who has perhaps spent even more time in pouring over plans, curves and tabulated data.

Accuracy and dispatch are the fundamentals of successful seamanship, and they are best obtained by practical observation of every appliance and fitting in the ship. When all things remained stationery, as in the times of sailing ships, the art of seamanship was largely formulated, and for every probable contingency the best line of action had been established by precedent. But to-day there is little or no precedent and nothing is formulated, for everything is changing.

The contingencies themselves are often unlooked for and the best procedure for one ship may be worst for the other. Unremitting vigilance and complete familiarity with every detail on the part of the officers are more necessary than ever before, because the men have not yet learned the requirements of the new seamanship, and much of their work must be done for them. This knowledge of detail is valuable in another way for it gives an insight into the causes of failure, and an appreciation of the uselessness of refinements that are seldom or never used. Without this knowledge proper suggestions for simplification and improvement cannot be made.

Roosevelt says: "The captains and lieutenants of 1812 had been taught their duties in a very practical school." It was to this knowledge of their duties that the perfection of our warships of that period was largely due, for they were able to suggest improvements of practical value to builders who had long been accustomed to constructing and equipping ships which could fight as well as they could run. To-day the value of proposed improvements is largely a matter of judgment based upon the behavior of the ship in peaceful cruises or manœuvres. How important, therefore, it is that no ideas or suggestions should be lost, particularly those which arise after some annoying or perplexing experience has shown the best way of overcoming some unforeseen difficulty. There have been numberless suggestions for improvement during wardroom discussions, but they have usually been forgotten.

It is thought that a "suggestion book," in which every officer would be encouraged to record the results of his individual experiences and his suggestions for improvement, would prove of interest and utility. If it were possible to adopt the German regimental system, and have occasional discussions by all officers of the various questions arising, and record the ruling opinions in the suggestion book it would be of still more value.

Such a book would have a twofold usefulness: for those afloat, it would accentuate the familiar fact that a ship is a compromise; that what is added to one quality must be taken from another, and by showing the cost of improvements, it would increase the desire for economy in order that the improvements could be carried out. For those ashore, it would show where improvement was most desirable, and it would recall the onerous conditions of sea service, which are so quickly forgotten after a few months of shore duty.

In suggesting and making improvements, however, let us avoid jumping at the conclusion that every new device makes obsolete everything preceding it; for it is the demand for perpetual change in minor details which fritters away money that could be more efficiently used on more vital alterations. The better way is to spend money only on those alterations that are absolutely necessary, until such time as the ship is laid up for a general overhauling and refitting. At that time, especially if the suggestion book has been utilized with the proper spirit, the money which has been saved on useless or unnecessary alterations can be expended to produce a harmonious whole or at least a complete development of one or more qualities, instead of having a patchwork of incomplete improvements which give satisfaction to no one. The knowledge that there is not sufficient money available for more improvements should increase the desire for frugality, as economy is a revenue in itself.

If simplicity and economy be carried out, as suggested in this paper, a more efficient ship can be built for the same money in the first place; there will be less expense in making good wear and tear; and the ship can be kept in line with the onward march of naval science.

The ideal seaman for the modern warship is admirably described by Luce: "The highest expression of the trained man is to be found in the able seaman and expert gunner combined." The necessary complication of hull and equipment requires from the men a reasonable amount of mechanical skill and capacity for their effective use and care. Much has been said and written concerning methods of training seamen and making them comfortable, and the writer merely wishes to call attention to some particular qualities which are touched on in this paper.

It is not possible for one man to have a thorough knowledge of the entire ship, and some specialists are therefore necessary, although there is little room for the man who knows one thing only. The most valuable men are those who know their own duties well, and who have a general knowledge of the duties of others, for they do their own work more efficiently, and do some portion of the work of others in an emergency. This is well recognized in the training of both officers and men; but greater efficiency can be obtained when we have a larger number of men who are mechanic-sailors; above everything else they must have the bold, self-reliant spirit of the old seamen. We want men who know what to do and how to do it, who are quick to see the necessity for action, and who are prompt to act without waiting for orders; such men cannot be mere sailors, for they lack the necessary mechanical skill; nor mere mechanics, for they lack the necessary knowledge of the sea, and their point of view is apt to be too narrow.

We have such men but we need more, and all should be taught a wider range of duties. The boys who can take apart and replace the breech mechanism of a rapid-fire gun can quickly learn to overhaul the gear for operating a water-tight door; and the men who know how to use and care for the torpedo plant can easily learn to care for the steering gear. The knowledge of drill and monkey-wrench is as important as that of marling-spike and mallet; and the skill to pack a stuffing-box or hand-pump, or to fit a rubber gasket is as necessary as the skill to reeve off a fish tackle, or a boat's falls, or to heave the lead. To get and keep the right man is not easy; he must get good pay and good treatment, but with them he must accept the altered conditions of the service, must feel his increased responsibility and must expect prompt punishment for every act of carelessness or negligence.

The lack of an American seafaring element to draw upon in war is a deplorable fact, but there is consolation in the thought that many valuable men can be had in war from another class. The new navy is popular throughout the country; and when the emergency arises it will require but small encouragement to obtain thousands of volunteers from the young, alert and self-reliant American artisans, who now find an abundance of well paid work on shore. Such men under capable petty officers, would quickly adapt themselves to sea life and the special mechanical appliances found on board the modern warship. After a few months' training they would be more valuable in the gun and powder divisions than the best north countrymen, who are sailors from instinct, but who do not have that adaptive and ingenious faculty which is peculiarly American. Seamen are more needed than ever before, for their special knowledge is absolutely essential. The experience of the Romans in the Punic wars, of the Spaniards with Armada, and of the French in the time of Napoleon, is sufficient to show that knowledge of wind and weather cannot be obtained by a royal decree or a general order; and that without this knowledge the proudest fleets are useless. But it is also true that only a small number of men who are seamen and nothing else is needed on our ships to-day where sails are conspicuous by their absence. There are certain duties which none but the seamen can perform; and even if this were not so, his presence is necessary for the fostering of those peculiar qualities which are needed by those who "go down to the sea in ships," even though it be on a floating battery which never sees blue water. The necessity for men who are more than mere seamen is recognized in the training given to the seamen gunners, and in the appointment of boatswains and gunners who have had this admirable training. With more such men, and with carpenters who have been navy yard apprentices, our ships will be more efficient and better cared for, and executive officers can devote less time to petty details, and occupy themselves in more important and congenial administrative duties, and economy will be more practicable.

To attain this desirable end with the crews of to-day, they must be made to realize that no duty is unimportant, that every man on the ship is there to perform as many duties as possible, and that carelessness is the worst of faults. They should feel that it is as discreditable to be ignorant of the leads and uses of pipes and electric wires now as it was to be ignorant of the leads and uses of the rigging. Petty officers in particular should know the use and care of every appliance and fitting in their part of the ship, and should be taught to foresee and meet the many emergencies which may arise. In the minute subdivision of the present war-ship, the petty officers must often be relied upon to remedy defects at once, instead of waiting for orders. In the action between the Constellation and l'Insurgente, Porter in the foretop, finding that his hails to the deck were disregarded when the foretopmast was badly wounded near the lower cap, cut the stoppers and lowered the yard, and thus insured the victory. Such appreciation of danger, and such prompt action to meet it, is a lesson to officers and men alike, for if Porter and his men had not been taught the use and necessity of this manœuvre it could not have been accomplished.

The superb condition of the ships coming from the Pacific for the Naval Rendezvous shows what may be done by proper training on long cruises. On the home station, however, one often sees a spirit of carelessness and recklessness that is opposed to efficiency and economy. To some extent, this may be due to the present unfortunate necessity for transferring men from ship to ship; the men have not time to learn their ship, and they feel little interest or responsibility in her.

But it is mainly due to the feeling that a navy yard is near by, and that the defects due to their own carelessness will there be made good by some one else, instead of by themselves. This can best be remedied by impressing every one that the appliances at hand must be utilized, and that the numerous small defects which are sure to occur must be made good on the ship whenever possible.

Many times victories have been won by sailing ships, merely from rapidity in repairing damages. After close cannonading without decisive results, although each ship had suffered severely from her opponent's fire, it was common for them to separate and attempt to repair damages; the one which was first able to haul into position to rake the other was certain of victory. It may be said that this is no longer true with the modern warship, as damages can only be made good at navy yards. This is only partially true, for there will be many minor injuries which can be repaired at sea, and with two ships similarly damaged, the one with a crew which is able to make even temporary repairs will be most efficient because she will be more formidable *en route* to a navy yard, and will be ready for active service sooner than the other. This is well illustrated by the behavior of the Japanese ships after the Yalu fight; and in our own Civil War, great delay and embarrassment were experienced from inefficiency and incompetence.

To keep the mechanic-sailor after he has been trained to his new duties, more pay must be offered him, or he will seek the higher wages to be found on shore. Yet true economy and efficiency will follow when this is done, for ships can be kept in a more perfect state of readiness, and the additional expense for pay will be much less than the expense of increased repairs due to ignorance or incompetence. It should be thoroughly understood, however, that any increase of pay must be accompanied by a strict accountability, and that any negligence will be followed by severe punishment.

Colomb says: "When man power is capable of doing the work, I cannot help thinking it is very much better, on board warships, that the man power should do it." This is exactly in accordance with the simplicity and economy advocated in this paper. Such fittings as the automatic whistle and the automatic steering compass are complicated and delicate, and their cost for installation and repairs is out of all proportion to their practical usefulness. The warship carries a sufficient complement to afford men to do the work of such devices, who thereby learn those habits of alertness and self-reliance which are so valuable. In manning boat falls, ash whip and fish tackle, coal is saved, and the crew exercised. A voice tube and annunciator to a military top may function reliably, but it is simpler and surer to hail the top from deck. It is better to abolish all small fittings which are not necessary and which are so unreliable that they may fail just when the men are accustomed to their use and depend upon them in emergencies. Larger appliances must be supplied for use when there are few men available, but their use should be restricted to such times, except when dispatch is required.

Soley's comparison of the actions between the Shannon and the Chesapeake, and between the Weehawken and the Atlanta might have been used as the text for this paper. He says: "In both cases the victorious captain . . . is bold and prudent, attentive to details, minutely careful in preparation"; the victorious ships were "always ready for any kind of service"; with the losers "there was the same absence of preparation." Ships and crews were as nearly perfect as the naval science of the day could make them, and that is what is wanted with the warship of to-day.

Perfection in the ship is not to be had by crowding her with complicated and fragile mechanisms or superfluous fittings upon which no reliance would be placed in war, and which are seldom, if ever, used in peace, even though the ship be fresh from a navy yard. True progress lies in supplying those appliances which are useful and reliable, and in subordinating their individual efficiency to that of the whole ship.

Perfection in the crew is to be had by encouraging versatility and by restoring the old spirit of self-reliance, so that the complicated fittings which are necessary on modern warships can be maintained in constant readiness for use.

Improvements are continually necessary; but they cannot be had unless economy provides the money, and they will rarely be of permanent value if they are the expression of hastily conceived notions, or cause a departure from simplicity.

Simplicity and economy cannot be secured by the efforts of the few; the concentrated desire of the many as manifested in their daily duties, can alone cause a lasting improvement. Complication has arisen from the demands of the entire service, and the remedy is in its hands, for it is only by the cordial cooperation of every one that the warship can be made an efficient weapon.

DISCUSSION.

Commander C. F. GOODRICH, U. S. N.:—A more timely article could not have been penned, nor one more urgently needed, to call attention, in tones not to be misunderstood, to a tendency of our service which is full of evil. Every officer who has served on board of a modern ship must have felt the inconvenience arising from break downs of delicate machinery and apparatus, upon which reliance had been placed until the habit of trusting to them had become fixed. Convenient and useful these machines and appliances are, but the question seems never to have been asked, Do they sufficiently increase the ships' fighting efficiency to justify their adoption? or, What provision has been made for doing their work in the event of failure during an action?

There are three systems which especially offend against the doctrine of simplicity—the electric call and alarm circuits, the drainage, and the auxiliaries.

It would seem as if officers had so clamored for easy communications that they had been granted electrical calls from each to every point on board, so numerous and so intricate are the leads in some instances. I should be afraid to say how large a percentage of these circuits I believe to be usually out of order. As to automatic alarms—their annunciators are as ornamental as they are doubtless costly—but, too often, the vital organs in the bilge and bunkers are out of order. Why *should* they replace that human vigilance which is the essential condition of safety? Would a captain be cleared of the charge of negligence if he lost his ship through failure of an electric alarm?

The writer has dwelt upon the drainage maze of pipes even less censuringly than he might. After what he has said it will be impossible in the future to repeat the errors of the past.

The auxiliaries should either be operated without steam, or they should be abolished rather than lead steam pipes through living spaces—I had almost written outside the engine and boiler compartments. Personally, I see no reason why all really vital to the ship's proper functions, should not be electrically driven. The electric motor is now in daily use on tram cars and under conditions which make shipboard employment a laboratory experiment in comparison.

The ventilation of our ships as at present designed is fraught with danger in the event of the sticking of the automatic valve and the consequent free passage of water from one water-tight compartment to another. I was told by Mr. Cramp that the air ducts for the New York covered one of his docks and stopped much yard work until gotten out of the way, and in their place on board where they took up the room of 300 tons of coal. I am not original in suggesting independent electrical ventilating fans at such points, *and such only*, where they are indispensable, discharging directly upwards through tubes that pierce no bulkhead. While this suggestion appears to involve a departure from simplicity, I think, upon study, it will be found to be within the author's limitations.

The proposed "manual" needs no endorsement, its value is axiomatic. The "suggestion book" is equally admirable. Personally, I have adopted its leading features by requiring my subordinates on board ship to submit to me written memoranda of their recommendations and criticism upon the hull and fittings for embodiment, at my discretion, in my periodical reports to the Bureau of Construction. I am loath to urge upon a service already deeply laden with papers and returns any additional burden of a clerical nature, but the manual and suggestion book seem sufficiently useful to meet even this objection.

It is not often that an article can command such hearty agreement as I am sure will meet this sermon on Simplicity. It is a contribution to the literature of the profession as notable for its subject as for the manner and style of its treatment.

I hope the author will pardon me if I rewrite one of his clauses and conclude by saying, "nothing should be added unless the advantages of its presence more than counterbalance the *advantages* of its absence."

Lieutenant H. S. KNAPP, U. S. N.:—The service is fortunate in having presented to it in such an able way the important subject of Mr. Baxter's essay, and I believe that his general conclusions will meet with hearty approval. To my mind, he strikes the key-note in his remark, "The man is the most important part of the ship's mechanism," and what he has said in that connection appeals especially to me as a sea-going officer. In the desire to surpass like ships in foreign navies, many of our own ships have been so filled up with weapons and machinery as to fatally crowd and discomfort the men. Heavy batteries, torpedoes and powerful machinery are all desirable, no doubt; but every addition in either direction involves additions to the complement, while, at the same time, there is less room for the greater number of men and for the increased supplies of all sorts required. The question is one of compromise, but the compromise should not ignore Jack; in too many of our new ships it does.

I am serving on board one of our smaller ships that admirably points the moral. On a displacement of about 2000 tons only she carries a main battery of nine 5-in. B. L. Rs. (it is proposed to add another), four automobile torpedoes of two distinct types, and the engines and auxiliaries develop 5400 I. H. P., giving a trial speed of a trifle over 19 knots. As a consequence, the cubical air space per man is much less than that required by statute for emigrants on ocean steamers. Considering the necessary heat from the boilers and dynamo-room, which latter is immediately below one compartment of the berth deck, it will be seen how crowded and uncomfortable the men are at night. Nor are they much better off by day, except in fine weather, for the forecastle is their only comfortable place when it is hot, and when it rains they cannot stay there. Bad as this is, considerably less berthing space was allowed in the original design, which provided for a somewhat heavier armament. I leave out of consideration the Gehenna-like side passages which were provided with hammock-hooks by some genius.

Lest I be accused of growling without suggesting a remedy, I will state briefly in what way changes might be made that would, in my opinion, result in a better ship. In the first place, I would leave out altogether the automobile torpedoes, of whose value, on small ships of the cruiser class, I am skeptical. But the great change that seems to me desirable is in the boiler power. Three-quarters of the power now installed, 4000 horses say, could be distributed in two double-ended and two single-ended boilers, and would give the ship a speed of 17 knots. This would result in the saving of space below and on the berth deck equal to the length of a single ended boiler plus the width of one fire-room. Below the berth deck a large additional coal space could be provided, together with increased hold and store-room space in which the ship is lamentably deficient. On the berth deck there would be an additional compartment available for berthing and messing space. The result would be a great increase in habitability, considerable gain in stowage room, increased coal capacity, increased radius at full speed of at least 700 miles, largely increased radius at cruising speed,* and a diminished number of auxiliaries, together with a smaller number of men. To offset these advantages there would be a sacrifice of two knots at extreme speed, though a 2000-ton ship is no laggard that can make 17 knots.

The changes proposed are all in the direction of simplicity. To my mind, however, the greatest gain of all would be in habitability, which must have an effect, and that so great as hardly to admit of exaggeration, on the efficiency of the ship as a war machine, especially if the proposed changes cross the line between comfort and discomfort. I am convinced that changes such as I have indicated would increase the efficiency and value of the ship for both peace and war.

My criticisms have been made on the one ship with which I am most familiar; but conversations with many brother officers convince me that, in a general way, they are true of almost all of our new ships of less than 5000 tons. I will trespass no further on the pages of the Proceedings, beyond expressing my belief that the sentiment of the service at large is entirely in accord with the spirit of Mr. Baxter's paper.

Lieutenant WM. F. FULLAM, U. S. N.:—Practical naval officers who go to sea in ships of war, who have opportunities to note the workings and defects of the many mechanical devices now supplied, and who have

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* From observed performances, the cruising radius at full speed, 19 knots, is about 1450 miles in 3¼ days; at 11 knots, 30 tons per day, 2800 miles in 10⅔ days. By the proposed changes these radii become: at full speed, 17 knots, 2225 miles in 5½ days; and at 11 knots, 30 tons per day, 3600 miles in 13⅔ days. It is estimated that 90 tons of coal more than the present capacity can be carried, with an allowance of about 1200 cubic feet for stowage in addition.

stopped to consider how these ingenious and labor-saving machines would probably fail and cause confusion in battle, will heartily welcome Mr. Baxter's article on "Simplicity." A few months' experience afloat should be enough to convince any man whose duty it is to study how to make ships efficient for the one emergency for which they exist, that we have passed beyond the limit fixed by practical considerations, in the introduction of complicated mechanical contrivances on board ship. It is fortunate indeed that Mr. Baxter has brought the subject up, and it will be equally unfortunate if the discussion does not bear good fruit.

It has too often been asserted that those who *use* weapons are not supposed to know much about the mechanism, and that they should not presume to criticize the design. This is an absurd theory, of course. The inventor should always be glad to utilize the experience, and to benefit by the advice, of the man who uses the arm. It is gratifying to note that Mr. Baxter recognizes this fact. The idea of a "suggestion book" on board every ship is an excellent one. It could be kept confidential, and only referred to by those who properly have occasion to deal with such questions.

Mr. Baxter covers the ground so thoroughly that there appears to be little chance for additional suggestions. I can take exception to no statement or argument in Mr. Baxter's paper, except in the one particular that the ice machine is an unnecessary "luxury." Even this statement may be perfectly sound as regards the majority of ships. But in the case of the Raleigh, the capacity of the fresh water tanks is so limited, and their situation is such, that the ice machine is a practical necessity for cooling the water for the men to drink.

In the limits assigned for a printed discussion, it is hardly possible to dwell upon the many important points of this valuable paper. But there is one idea that demands special attention. Mr. Baxter has recognized that, after all, the *man* is the most important machine on board a fighting ship; that he must be kept in good condition; that he must not be crowded out by other machines; that he must be given space in which to live like a human being. "Every one having experience on the new ships feels the necessity for larger crews in war, the present complements being inadequate to perform the many responsible and onerous duties required to secure anything like continuous efficiency; they can stand the pressure during a few hours of excitement, but the continued strain of watching and waiting for the enemy must be distributed among more men in order that everything shall be ready when he appears." This statement is sound. And to the "strain of watching and waiting for the enemy," we must add the strain of coaling and cleaning ship. There are not enough men to bear the burden and drudgery of routine work afloat.

The essayist displays sound judgment regarding the *kind* of men needed in the modern ship as well as the number. A Pinafore theory that the day of the sailor is passed is being urged by certain individuals who see "as through a glass-eye darkly." Because *sails* are abolished they think the sailor has no place on board a modern ship! His usefulness, they think, is measured by the first syllable of his name—"sail." But this argument is not deep. It cuts both ways—this play upon syllables. It has been well said that "the sailor is also a *sea*man, and the *sea* has not yet been *abolished*." As long as there is water enough to float the navy, we shall need seamen. The necessity for seamen is daily felt by officers on board mastless ships. Their training should be somewhat different, as Mr. Baxter says, but not so different as many people imagine who have nothing but imagination as a basis for their opinions. There is hardly a quality of the old-time sailor that is not needed in the man-of-war's man of to-day. Something should be added, but little taken away, to convert the man of the past into the man of to-day. The change can be made with great ease. With the seaman, we simply have to add *one* quality to the *ten* he already possesses. With any other man, we should have to add *ten* qualities to the *one* he already possesses. Let us take the simplest solution and stick to the best man.

When naval architects recognize the vital importance of the human "machine"; when they provide for the stowage of *men* as well as for the stowage of *material*, we may hope that line officers will give more attention to the subject. To bring the man to the highest possible state of efficiency; to attend to the "care and preservation" of *this* piece of mechanism, is peculiarly their function—it is their first and most important duty. And they should not approach the subject with timidity, but with the fearlessness and practical sense that should distinguish those who may command ships and squadrons in battle. Questions regarding the *number* of men, the *kind* of men, and the *development* of men have not received their proper share of attention. Officers are court-martialed for permitting iron to rust, and machinery to deteriorate. They are encouraged or forced to devote too much time and thought to naval material. They hesitate, for various reasons, to deal courageously and thoroughly with the one question that most vitally affects the fighting efficiency of the navy—the question of *men*.

Lieutenant JOHN M. ELLICOTT, U. S. N.:—In his "Suggestions for Increasing the Efficiency of our New Ships," Naval Constructor Baxter has given to the service a most fortunate and opportune paper.

In reconstructing our navy we have built ships of every type, and with many variations in each type, so that, with our first battleships now completed, we have just reached the point where we can compare the results and eliminate, simplify and standardize for future construction. Agreeing then as I do with nearly every suggestion in the paper toward simplicity in the fittings of our men-of-war, I cannot help feeling regret and disappointment that the author avoids the very groundwork of simplicity, the standardizing of designs.

Mr. Baxter states truly that "standardizing is the most obvious means of securing simplicity," and that "standardizing reached its highest perfection at the opening of the century, when *ships of the same type were practically alike from keel to truck*," but almost immediately afterward, he abandons these important premises by saying, "the question of design is too large for consideration."

On the contrary, it seems to me that unless we begin with the question of design, the question of simplicity in fittings becomes almost too large for consideration. I believe that in the Indiana, New York, Columbia and the Newport News gunboats we have reached best adapted types, and that their designs could be adopted as standards in their respective classes to such an extent that variations from them would not materially affect the standardizing of mechanism and of its distribution and fittings in them as adopted standards of design.

It therefore seems to me that we could succeed in standardizing and simplifying our men-of-war and their fitting, in the following manner: let the Board of Bureau Chiefs advise the Secretary of the Navy which of our new men-of-war most nearly represent standards in each class and type. Let the Secretary then assign a naval constructor to each ship so designated, to cruise on her during some period of manœuver which will fully test her efficiency for the purpose for which she was built, as a member of a "Standardizing Board," composed, beside himself, of the captain of the ship, the executive officer and the chief engineer; this board to decide upon standard types of auxiliaries, standardized localities for same, standardized leads for all conduits, and to advise upon equipments which can be discarded; having always in mind the efficiency of the ship as a fighting machine. Let the plans of these boards, after being passed upon by the Board of Bureau Chiefs, be adopted as standardized plans for interior fittings, and in future construction let these plans be followed as nearly as the ships' designs will permit, until in some parts there is discovered room for obvious improvement. It strikes me that such a method of procedure would be more directly to the point, and have a more exact end in view than the keeping of "suggestion books."

I should like to ask the writer why he regards hydraulic or electric motors, "clearly undesirable at present," for capstan and steering engines.

I shall be sorry to see voice pipes condemned as "cumbersome," "dangerous" and unreliable," until that "suitable telephone" suggested by the writer shall have been developed. I cannot see that voice pipes are particularly cumbersome or dangerous, and they are chiefly unreliable, because poorly installed. They are fitted too much like water spouting, with sharp angles at every change of direction, these changes, too, being often unnecessarily numerous. Easy curves at such points and a minimum of turns would render the pipes absolutely reliable for the transmission of orders until cut by shell. Duplication of pipes to vital points with different leads would reduce the chances of that misfortune. I do not believe in a central station for voice pipes, but in separate pipes connecting all important stations between which the voice alone would not carry, manual signaling would be impracticable, or messenger service too slow in battle. Such pipes, by following as far as practicable other conduit leads, would not detract from simplicity. Many voice pipes now installed are redundant, while more important connections are lacking.

As for telephones, they will function afloat *in peace* as well as they do on shore, but what officer at all familiar with the not infrequent vexations of intercourse over the ordinary commercial telephones would place any reliance in the best installment of such instruments on a battleship amid the din of combat? Let us give more thought, then, to voice pipes, for the time may come when one properly installed will win a battle.

It will be noted that it is chiefly for what he has left unsaid that I criticise Mr. Baxter. What he has said, with the exceptions noted, strikes me as so opportune, so important and so correctly suggestive, that I should like to see a paper by him on standardizing designs, even though he now regards the subject as too large for consideration.

Naval Constructor W. J. BAXTER, U. S. N.:—This favorable discussion encourages the writer to hope that the service at large will be more willing in the future to do its part to secure the benefits arising from "Simplicity."

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

Οἱ μὲν θεοὶ πάντα ἀνθρώποις πωλοῦσιν, ὁ δὲ μισθὸς ἔργον.

THE BATTLE OF THE YALU.

By Ensign Frank Marble, U. S. Navy.

The following account of the battle fought between the Chinese and Japanese fleets off the mouth of the Yalu river on September 17, 1894, is based upon the reports printed in the *Army and Navy Gazette*, London, Sept. 22 to Dec. 1; the *Engineer*, London, Oct. 5; *le Yacht*, Paris, Sept. 29, Oct. 6, and Dec. 1; the *Japan Daily Mail*, Yokohama, Oct. 11; the *New York Herald*, Nov. 7; the *New York Times*, Dec. 9; and several letters in the *London Times* and other papers. The clearest accounts of the manœuvres of the two fleets are found in the Japanese official reports, printed in the *Japan Mail* of Oct. 11 and *le Yacht* of Oct. 6.

About the 12th of September the Chinese fleet under Admiral Ting was assembled in Port Arthur, under orders to convoy a fleet of six or seven transports from Talien Wan—25 miles northeast of Port Arthur—to Wiju, at the mouth of the Yalu river. The first reports were that this fleet sailed on the 14th, the later ones that it started in haste upon receipt of news of the victory of the Japanese army and the capture of the citadel of Ping Yang, which occurred early in the morning of the 15th. However this may be, the Chinese fleet with the transports in convoy arrived in the Yalu, which is about 200 miles from Port Arthur, on the afternoon of the 16th; and the transports proceeded up the river to disembark their troops.*

The Japanese fleet, in the meantime, had been in the Ping Yang inlet acting in concert with the army, and after the victory there

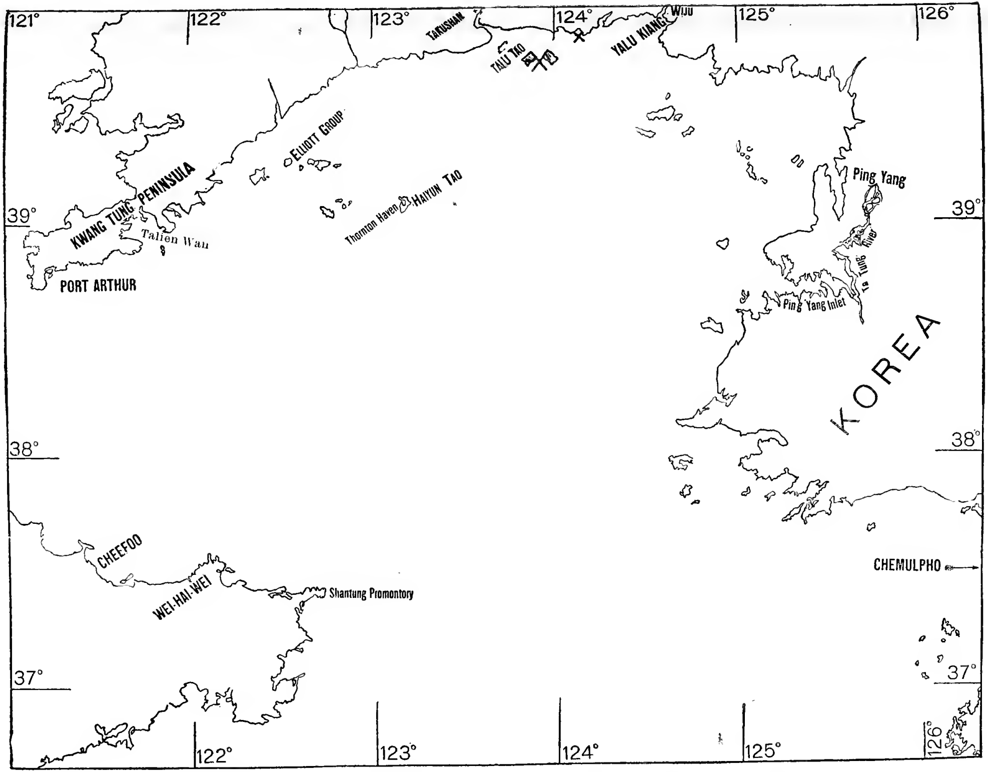
*Later reports seem to indicate that the troops were landed in the inlet west of the Yalu, where the fleet was found by the Japanese.

had gone northward to a "temporary anchorage" or rendezvous, whose exact position is not given, but which must have been in the eastern part of the Bay of Korea, some distance to the southward of the Yalu. At 5 p. m. on the 16th, the fleet, under Admiral Ito, sailed from this anchorage in search of the Chinese, steering for the island of Hai Yun, which is nearly in the course from Port Arthur to the Yalu and about midway between the two. At 6.30 a. m. on the 17th this island was reached, and the Akagi sent forward to reconnoitre the inner harbor of Thornton Haven. Finding no enemy the fleet steered for Talu Tao, off Taku Shan, 45 miles northeast of Hai Yun Tao and 40 miles westward of the Yalu, which island was sighted on the port bow at 10 a. m. Between 11 and 11.30 the van division signaled smoke to the east-northeast; and a few minutes past noon, the enemy having been recognized, the signal was made to prepare for action.

The Chinese opened fire at 10 minutes before 1, at a distance of 5000 or 6000 meters.

The first reports gave the position of the Chinese fleet across the mouth of the Yalu river; but later information, corroborating the inference from the times and distances just given, shows that it was lying in Takuo-hoa, or Taku-chad, or Ta-Tau-K'ou Bay, or inlet,—which is not marked on the Intelligence Office chart, but the position of which is given in Lat. 39° 47′ N., Long. 124° 7′ E.; that is, on the coast of Manchuria about 15 miles east of the Talu Tao and nearly 25 miles west of the Yalu. This position is marked on the accompanying chart by a cross. At the approach of the Japanese fleet the Chinese steamed out to meet them. The battle was fought in the open sea, and there is no reason to believe that either fleet was hindered in its manœuvring by shoals; nor was the Chinese, as was first stated, hampered by the presence of its transports. The sky was overcast, the sea rough, and the wind fresh from the east.

The composition of the two fleets is given in the following tables, which are taken from a paper by Secretary Herbert in the *North American Review* for November. Two ships omitted from the list of the Chinese fleet have been inserted in the table, and a column added giving the secondary batteries of the ships. These tables are based upon the publications of the Office of Naval Intelligence, and give the most accurate description of the ships


121°
122°
123°
124°
125°
126°
39°
38°
37°
KWANG TUNG PENINSULA
Talien Wan
PORT ARTHUR
ELLIOTT GROUP
Thornton Haven
HAIYUN TAO
TAKUSHAN
TALU TAO
YALU KIANG
WIJU
Ping Yang
Ta Tung River
Ping Yang Inlet
KOREA
CHEMULPHO
CHEEFOO
WEI-HAI-WEI
Shantung Promontory

that has been printed. It may be noted that all the English papers, following the repeated inaccuracies of Brassey's *Naval Annual* for 1892, 1893 and 1894, give the Akitsushima the same battery as the three sister-ships Itskushima, Matsushima, and Hasidate; and their enumeration of the guns of the Japanese fleet is consequently erroneous. The tables in the *Army and Navy Gazette* contain besides some typographical errors. There is of course considerable diversity in the spelling of the names. Most of the English papers spell Chi Yuen "Tsi Yuen." The spelling here followed is that adopted by the Intelligence Office.

In addition to the ships given in the tables, the Chinese had three or four torpedo-boats (one report says that only one of these took part in the action), besides two 65-ft. boats hoisted on board each of the two battleships; and the Japanese had an armed mail steamer, the Saikyo Maru, in which Admiral Kabayama, of the naval general staff, was embarked on a tour of inspection.

It is not easy to estimate the relative strength of two such heterogeneous fleets. In numbers the Chinese were 12 to the Japanese 11. Considering that the little Akagi, with her two guns, is not much more than half the size of the smallest of the Chinese ships, and that she had no regular place in the formation, the slight numerical superiority of the Chinese is more marked. As to size, although the biggest two Chinese are bigger than the biggest three Japanese ships together, the average size of the Japanese ships is larger, and the total displacement of their 11 is greater than the total of the Chinese 12. In speed the Japanese had a great advantage. The figures in the table are maximum trial speeds, and it is not likely that either fleet attained its maximum in the engagement, but the figures may serve for comparison. The *average* of the Chinese fleet is 16 knots, the Japanese 17. The Japanese had three slow ships, the Fuso, Hiyei and Akagi, of 13 to 14 knots maximum, which were put in the rear of their column, and Admiral Ito did not always wait for them; the remainder of his fleet could go 16 knots or better, and his van was led by one of the fastest ships in the world. The Ping Yuen of the Chinese fleet had a maximum of only 10.5 knots, and even if she were left out—she seems to have played but a small part in the action—the remainder of the fleet could not keep more than 15 knots together. Considering that with the exception of the slow Ping Yuen and

CHINESE SHIPS ENGAGED IN THE ACTION OFF THE YALU RIVER.

Name.	Class.	Displacement, tons.	I. H. P.	Main Batteries.		Secondary Batteries.	Torp. tubes.	Armor.			Max. speed, knots.	Completed.
				No. and class of guns.	Total wt. of fire, lbs.	No. and class of guns.		Hull.	Battery.	Deck.		
a Chen Yuen...	Battleship	7,430	7,300	IV. 12.0″ B. L. II. 6.0″ B. L.	3,126	VIII. H. R. C. II. 3″..........	3	Belt, Partial, 8–14″	Barbette, 12″	2–3″	15.5	1883, Germany.
b Ting Yuen...	Battleship	7,430	7,200	IV. 12.0″ B. L. II. 6.0″ B. L.	3,126	VIII. H. R. C. II. 3″..........	3	Belt, Partial, 8–14″	Barbette, 12″	2–3″	15.4	1883, "
c King Yuen....	Coast defense vessel	2,900	5,000	II. 8.3″ B. L. III. 6.0″ B. L.	954	VII. H. R. C....................	4	Belt, Partial, 5.25–9.5″	....	....	15.0	1887, "
d Lai Yuen.....	Coast defense vessel	2,900	5,000	II. 8.3″ B. L. III. 6.0″ B. L.	954	VII. H. R. C....................	4	Belt, Partial, 5.25–9.5″	....	....	15.0	1887, "
e Ping Yuen....	Coast defense vessel	2,600	2,400	I. 10.2″ B. L. II. 6.0″ B. L.	637	VIII. R. F. G....................	4	Belt 8″	Turret, 5″	2″	10.5	1890, Foochow.
f Chi Yuen.....	Coast defense vessel	2,355	2,800	II. 8.3″ B. L. I. 6.0″ B. L.	730	VIII. H. R. C. II.—..........	4	4″ steel coffer-dams	Barbette, 15″	1.5–3″	17.5	1884, Germany.
g Chih Yuen....	Protected cruiser	2,300	6,000	III. 8.3″ B. L. II. 6.0″ B. L.	1,124	VIII. 6-pdr. R. F. G. II. Gat....	4	....	....	2–4″	18.5	1887, England.
h Ching Yuen..	Protected cruiser	2,300	6,000	III. 8.3″ B. L. II. 6.0″ B. L.	1,124	VIII. 6-pdr. R. F. G. II. Gat....	4	....	....	2–4″	18.5	1887, "
i Yang Wei....	Gunvessel	1,350	2,800	II. 10.0″ B. L. IV. 4.7″ B. L.	1,180	IV. H. R. C. II. Nord II. 9-pdrs. IV. Gat.	3	....	....	Partial 2–5″	16.2	1881, "
j Chao Yung...	Gunvessel	1,350	2,800	II. 10.0″ B. L. IV. 4.7″ B. L.	1,180	IV. H. R. C. II. Nord II. 9-pdrs. IV. Gat.	3	....	....	Partial 2–5″	16.2	1881, "
k Kuang Ting..	Gunvessel	1,030	2,400	III. 4.7″ B. L.	138	XII. R. F. G....................	4	....	....	1″	16.5	1892, Foochow.
l Kuang Ki....	Gunvessel	1,030	2,400	III. 4.7″ B. L.	138	XII. R. F. G....................	4	....	....	1″	16.5	1892, "
Total, 12...		34,975	52,100	12.0″ = 8 10.2″ = 1 10.0″ = 4 8.3″ = 12 6.0″ = 17 4.7″ = 14 Total = 56	14,411	H. R. C................46 R. F. G................48 Gatlings...............12 Nordenfeldt............ 4 9-pdrs., 3″, etc.........10 Total = 120	44					

JAPANESE SHIPS ENGAGED IN THE ACTION OFF THE YALU RIVER.

Name.	Displacement, tons.	Class.	I. H. P.	Main Batteries.		Secondary Batteries		Armor.			Max. speed, knots.	Completed.
				No. and class of guns.	Total wt. of fire, lbs.	No. and class of guns.	Torp. tubes.	Hull.	Battery.	Deck.		
1 Matsushima..	4,277	Coast defense vessel	5,400	I. 12.6″ B. L. R. XII. 4.72″ R. F.	1,416	VI. 6-pdr. XII. 3-pdr. R. F. G. 3 or more machine guns.	4	....	Barbette turret, 11.8″	1.5–2″	16.0	1891, France.
2 Itsukushima.	4,277	Coast defense vessel	5,400	I. 12.6″ B. L. R. XI. 4.72″ R. F.	1,370	VI. 6-pdr. XII. 3-pdr. R. F. G. 3 or more machine guns.	4	....	Barbette turret, 11.8″	1.5–2″	16.8	1891, "
3 Hasidate....	4,277	Coast defense vessel	5,400	I. 12.6″ B. L. R. XI. 4.72″ R. F.	1,370	VI. 6-pdr. XII. 3-pdr. R. F. G. 3 or more machine guns.	4	....	Barbette turret, 11.8″	1.5–2″	16.0	1894, Japan.
4 Fuso........	3,717	Armored cruiser	3,500	IV. 9.5″ B. L. II. 6.8″ B. L.	1,460	V. Nord. 1″. II. B. L. R.........	..	Belt, 8–9″	9–8″	....	13.2	1878, England.
5 Chiyoda.....	2,450	Armored cruiser	5,600	X. 4.72″ R. F.	460	XIV. 3-pdr. R. F. G. III. Gat.....	3	Partial belt, 4.6″	....	1–2″	19.0	1890, "
6 Hiyei........	2,250	Armored cruiser	2,490	III. 6.8″ B. L. R. VI. 6.0″ B. L. R.	1,028	IV. Nord. 1″	2	Partial belt, 4″	....	....	14.0	1878, "
7 Naniwa......	3,650	Protected cruiser	7,235	II. 10.2″ B. L. R. VI. 6.0″ B. L. R.	1,499	II. 6-pdr. X. Nord. 1″. IV. Gat...	4	....	....	2–3″	18.9	1886, "
8 Takachiho...	3,650	Protected cruiser	7,500	II. 10.2″ B. L. R. VI. 6.0″ B. L. R.	1,499	II. 6-pdr. X. Nord. 1″. IV. Gat...	4	....	....	2–3″	17.9	1886, "
9 Yoshino.....	4,150	Protected cruiser	15,000	IV. 6.0″ B. L. R. VIII. 4.7″ R. F.	760	XXII. 3-pdr. R. F. G.............	5	....	....	1.75–4.5″	23.0	1893, "
10 Akitsushima.	3,150	Protected cruiser	8,400	IV. 6.0″ B. L. R. VI. 4.7″ R. F.	670	X. 3-pdr. R. F. G. several machine guns.	4	....	....	2–3″	19.0	1894, Japan.
11 Akagi.......	614	Gunvessel	700	I. 8.2″ B. L. R. I. 4.7″ R. F.	354	II. Nord. 1″......................	..	....	....	....	13.0	1890, "
Total, 11...	36,462		66,025	12.6″ = 3 10.2″ = 4 9.5″ = 4 8.2″ = 1 6.8″ = 5 6.0″ = 26 4.72″ = 59 Total ..102	11,886	6-pdr. R. F. G..........22 3 pdr. R. F. G..........82 Nordenfeldt............31 Gatling.................11 Machine guns, etc......15 Total......161	34					

the two small gunboats, built at Foochow in 1890 and 1892, all the Chinese ships were completed in 1887 or earlier; and that of the Japanese, with the exception of two old ships—Fuso and Hiyei—built in 1878, two were completed in 1886 and the rest all since 1890; and remembering that the Japanese ships are kept in much more efficient condition than the Chinese, and are better manned; it is probably not too much to say that Admiral Ito had an advantage in speed over Admiral Ting of at least 2 knots with the main division of his fleet, and not less than 5 with his swifter van.

Comparing now the armaments and armor of the two fleets:—the Japanese had nearly twice as many guns in their main batteries as the Chinese; but the Chinese had more heavy guns and could discharge considerably greater weight of metal at a broadside, though much less in a given time. In estimating the relative value of the two batteries on a particular occasion, the armor opposed to them must of course be taken into account. A more detailed comparison of the calibers may be made as follows:—

Guns.	10″ and over.	Below 10″, over 6″.	6″ and 4.7″.
Chinese,	13	12	31
Japanese,	7	10	85

Of guns fit to pierce heavy armor the Chinese had 13 to the Japanese 7. But the Japanese had no heavy armor to be pierced, except the turrets of the three sister coast defense vessels (so called), and the slow old Fuso. The Chinese, properly speaking, had only two heavily armored ships. There were, it is true, the Chi Yuen, with a 15″ barbette and no other armor, the King Yuen and Lai Yuen with 8″ turrets and belts of 9½″ to 5¼″—but only partial belts extending only 2 feet above water,—and the wretched little Ping Yuen, with her 8 inches of armor, 10½ knots speed and 3 guns;—but what sort of armored ships were they? In guns able to pierce lighter armor the two fleets were nearly equal. Of the smaller calibers the Japanese had almost three times as many; and moreover, all their 4.7″ guns and none of the Chinese were rapid-fire guns. In secondary batteries the superiority of the Japanese was even more marked. They had in all 161 guns to the Chinese 120.

	6-pdr. and 3-pdr. R. F. G.	H. R. C.	Gatling and Nordenfeldt.	Misc.
Chinese,	48	46	16	10
Japanese,	104	..	57	..

Of these, 104 were 6-pdr. and 3-pdr. rapid-fire guns, and 57 Gatling and Nordenfeldt machine-guns. The Chinese had only 48 rapid-fire guns and 16 Gatlings and Nordenfeldts, and also 46 Hotchkiss revolver cannon and 10 miscellaneous light guns, which last were boat howitzers, etc., and probably were not used at all. The Japanese had very few guns able to do any serious harm to the two heavy Chinese ironclads, but on the other hand it cannot be doubted that the Chinese would have been better off had all the heavy guns in their smaller ships been replaced by lighter quick-firing pieces.

In torpedoes the Chinese were decidedly superior, having 44 tubes to their enemies' 34, besides 4 torpedo-boats. It is open to question, however, whether they had that many tubes or torpedoes ready for action.

On the whole, considering the adversaries to which they were opposed, it is the opinion of the writer that the Japanese fleet, although none of its ships were quite a match for the best two Chinese, was decidedly superior in strength.

The following plans of the action are made up chiefly from Admiral Ito's report as published in the *Japan Mail*, Oct. 11. They differ somewhat from the plans given by Lieutenant Naoki Miyaoka, the Japanese naval attaché at Washington, in the *New York Times*, Dec. 9, which are the same as those in the *New York Herald* of Nov. 7, taken from the *Jiji-Shimpo* of Tokyo of Oct. 2. A good deal has to be left to conjecture. No attempt is made here to represent the manœuvres in the last part of the action. The order of the ships in the Chinese formation, as well as the formation itself, can only be taken as approximate. The two gunboats, Kuang Ting and Kuang Ki, and perhaps the Ping Yuen, probably reached their stations some time after the action had begun. The order of the Japanese ships in column is more nearly certain. The Naniwa may have been the fourth ship instead of the second, and the Chiyoda may have been next astern of the flagship; but these differences are immaterial.

The Chinese fleet, as it steamed out to meet its fate, formed in an irregular line, or crescent, or double echelon, or V, or "two converging columns," according to the various accounts, which all agree that it was in great disorder. The actual formation probably was not the result of deliberate choice, but the order in which the ships found themselves in their unskillful attempt to get into some sort of line abreast. The battleships Ting Yuen and Chen Yuen were in the centre, flanked by the Lai Yuen and King Yuen, with the weakest vessels on the flanks. The Japanese fleet advanced in single column. The van division, commanded by Admiral Teuboi, was composed of the swift protected cruisers Yoshino, Naniwa, Takachiho, and Akitsushima. Then came the flagship Matsushima and her two sisters, then the Chiyoda, Fuso and Hiyei. The Akagi and Saikyo Maru were at first on the flank of the centre and rear divisions of the fleet; but the Saikyo, being ordered to avoid fighting, dropped to the rear,—though she afterwards joined in the battle,—and the Akagi, unable to keep up, was left behind.

The Japanese column first steered for the centre of the enemy's line, then gradually changed course to port, so as to come into action with its right wing. The Chinese opened fire at very long range; the Japanese replied at 3000 meters. The battle was fought in general at ranges from 2000 to 3000 meters. The Japanese van passed around the Chinese right flank and along their rear, apparently increasing its distance from the centre and rear divisions, which, led by Admiral Ito's flagship, performed the same manœuvre, defiling past the enemy's front as the van enveloped his rear. The Chinese order was thrown into great confusion, their right wing attacked on both sides by the whole of the Japanese fleet, their left out of action altogether. Admiral Ting's flagship and her sister ironclad headed for the enemy's centre, endeavoring to keep bows on, while the rest of the fleet steered in different directions, as if to engage separate vessels. Both sides kept up a hot fire.

As the Japanese centre and rear divisions passed in turn around the Chinese flank, their slowest ships, the Fuso and Hiyei, came within shorter and shorter range; and finally the captain of the Hiyei, which brought up the rear, seeing that by holding his course he could not clear the enemy's line, boldly steered between the two Chinese battleships, passed through their line, receiving and returning their fire, and rejoined his squadron on the opposite

EXPLANATION ON THE FIGURES.

In each of these figures, two successive positions of the fleets are represented. The first position is shown by outlined, the second by shaded and solid ships, the Japanese ships being shaded and the Chinese solid. The first position in Fig. 2 is the same as the second in Fig. 1. The ships are numbered and lettered to correspond with the list in the foregoing tables, as follows:

JAPANESE.

1. Matsushima (flag).
2. Itsukushima.
3. Hasidate.
4. Fuso.
5. Chiyoda.
6. Hiyei.
7. Naniwa.
8. Takachiho.
9. Yoshino.
10. Akitsushima.
11. Akagi.
12. Saikyo Maru.

CHINESE.

a. Chen Yuen.
b. Ting Yuen (flag).
c. King Yuen.
d. Lai Yuen.
e. Ping Yuen.
f. Chi Yuen.
g. Chih Yuen.
h. Ching Yuen.
i. Yang Wei.
j. Chao Yung.
k. Kuang Ting.
l. Kuang Ki.

The four ships in the upper right-hand corner of Fig. 2 represent the Akagi chased by three Chinese ships, and of course this part is not simultaneous with the rest of the figure.

FIG. 1.

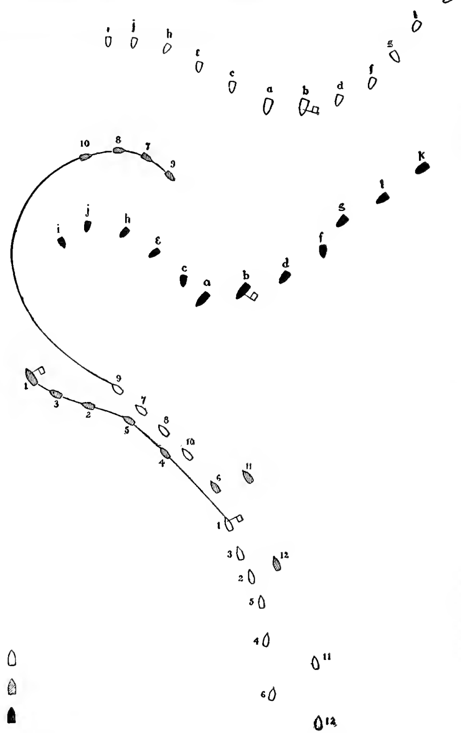
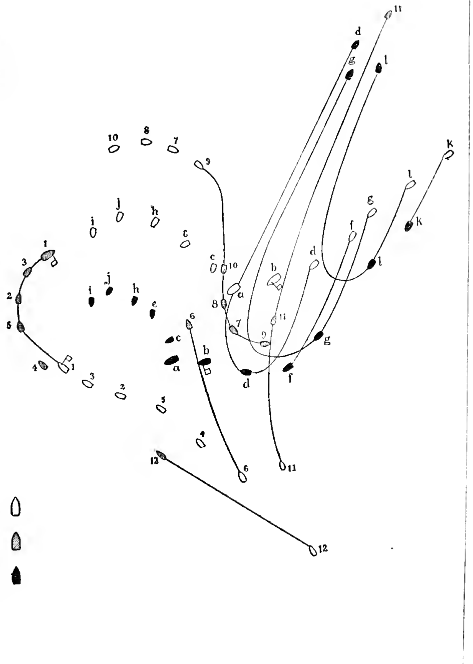


FIG. 2.



side. The little Akagi also appears to have broken through the enemy's line, somewhere to the left of its centre; and three Chinese ships passed under her stern within 800 meters. A shell struck her bridge, killed the captain and several men, and wounded several others; her forward magazine was destroyed and a steam pipe shattered. The first lieutenant took command of the ship. The Japanese van division, headed by the Yoshino, then, seeing the peril of the Hiyei and Akagi, instead of leading down the enemy's rear, changed course more to starboard and steamed at full speed to the rescue, pushed between the Akagi and her assailants, pouring their starboard broadsides into the latter as they passed. This again enveloped the Chinese right wing between two fires. [At this point the plans here given differ from those of Lieutenant Miyaoka and the *Jiji-Shimpo*. The latter represent the van division turning with starboard helm, and passing a second time entirely around the Chinese right flank, outside and in opposite direction to the Japanese centre division. The plan here given (which was made before these two were published) is believed to represent the movement more truly. Otherwise the van of the Japanese fleet must have been separated for a considerable time from the Chinese by its own centre and rear divisions, and must have turned its port broadsides toward the enemy. Whereas Admiral Ito explicitly says the Hiyei had passed through the Chinese line, and his van went to rescue her as well as the Akagi, and poured in their starboard broadsides as they passed, and "thus the enemy was placed between the fires" of the two divisions.]

The Hiyei about this time signaled that she had taken fire, and together with the Akagi retired from the action. Three Chinese ships, the Lai Yuen, Chih Yuen and Kuang Ki, pursued first the Hiyei and then the Akagi; but that brave little ship, in spite of the damage to her steam pipe, managed to keep ahead of them, working her stern gun with the utmost rapidity and with good effect. The commanding officer of the Akagi went into the maintop to look out for torpedo-boats, and signaled their movements by flags to the other ships. The Lai Yuen got within 300 meters; a shell from her struck the Akagi's bridge and wounded the navigator, who resumed his post as soon as his wounds were dressed; several shots hit her mainmast and finally brought it down, killing the commanding officer and two men on the lookout aloft; but at last a shell from the Akagi's stern gun set her pursuers' quarter-deck on fire, and in the midst of the confusion the other two Chinese ships stopped to succor her, and the Akagi escaped. After repairing her steam pipe she rejoined the fleet three or four hours later.* The Chih Yuen returned to the battle-ground; the Lai Yuen was too much damaged to take any further part in the fight; and the Kuang Ki was not heard of more.

There is some mention in one or two accounts of the Chinese fleet being reinforced in the midst of the action, and Admiral Ito states the numbers reported to have joined the enemy at this time as six torpedo-boats and four men-of-war. It is doubtful if so many joined, as their names are not given and there is no more detailed account of their part in the action, the course of which they certainly did not affect. If men-of-war, they were probably one or two of the small alphabetical gunboats. It is more probable that two or three of the Chinese fleet were so far behind in coming into action as to be mistaken by Admiral Ito for reinforcements, for he gives the original force of the Chinese ten ships instead of twelve.

In the meantime the centre and right of Admiral Ting's fleet continued in hot action. Admiral Ting was wounded 20 minutes after the fight began, in the following peculiar manner: He is reported to have been standing on the bridge, and to have been warned that he was in a dangerous place, but refused to move. One of the barbette guns when trained across came under the bridge; the admiral was thrown in the air, his right leg hit by splinters, and his face burnt. Commodore Liu Tai Tsan then took

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*It is uncertain whether both the captain and the first lieutenant or only the captain of the Akagi was killed. The "report of the Akagi" in the *Japan Mail* says that the captain was killed at 1.25 p. m. by a shell striking the bridge, but makes no mention of either the captain or first lieutenant being aloft and being killed by the fall of the mast, which happened some time later; but it mentions the name of the lieutenant who "took the place of the navigating officer and commanded the vessel" (for 8 minutes, from 2.15 to 2.23) while the latter was having his wounds dressed. The report of Admiral Ito's aide-de-camp to the Mikado, on the other hand, says that the captain was aloft and was killed by the fall of the mast, and that the first lieutenant then took command. The lists of casualties published in the *Army and Navy Gazette* credit the Akagi with only one officer killed.

command of the fleet.* All four—or possibly only two—of the Chen Yuen's heavy guns—which are mounted in pairs, covered only by $\frac{7}{8}''$ hoods, within an irregular shaped barbette redoubt—were knocked out of service early in the fight, apparently by a single lucky shot; and she was reduced to the two 6″ guns in the bow and stern.

The Yang Wei and Chao Yung, which occupied the extreme right of the line, where they received the fire of the whole Japanese fleet in passing, were by this time out of action,—the former retiring slowly shorewards in the direction of Talu Tao, the latter run upon a rock,—both enveloped in flames. Finally the Yang Wei was beached; and the Chao Yung, settling aft, went down in deep water, her upper masts remaining above the surface. Her miserable crew took refuge in the rigging, but the battle was too furious for friend or foe to heed their cries. The Kuang Ting also, from her position in the left wing, passed by the Chinese flagship and fled toward the shore. The Chi Yuen also withdrew early in the day, all three of her gun carriages having got out of gear, though not from any damage by the enemy's fire.

The descriptions of the manœuvres in the latter part of the action are extremely vague. It is evident that the Chinese order was thrown into entire confusion. Admiral Ito's main division, keeping its formation of single column to the last, is reported to have circled around what was left of the Chinese fleet, and even to have repeated the manœuvre three times. After a time the Chinese flagship tried to close, apparently with a view to ramming. She broke the formation and with two or three other ships charged at full speed. Admiral Ito reports that at half past two the Ting Yuen steamed past the front of his squadron,—"but she received such a storm of projectiles that her crew seemed to fall into a state of the greatest confusion, and presently she took fire." The King Yuen also was severely crippled in the attempt. The enemy's fire was concentrated upon the disabled ships and especially upon her. She tried to escape, but the Japanese van gave chase, leaving the main division engaged with the sister ironclads. Finally the King Yuen was sunk. Her gunners remained at their pieces

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* He it is that has since committed suicide in consequence of having stranded the Chen Yuen in attempting to avoid the submarine mines in the harbor of Wei-Hai-Wei.

until the last minute. She went down slowly, stern first; her bow rose out of the water, remained a minute and a half in that position, then disappeared forever. In the Japanese fleet "the enthusiasm was indescribable, the crews redoubled their ardor, the officers exulted in satisfaction."

About this time the Chih Yuen, which had returned from the chase of the Akagi, went down with all on board. The manner of her loss is uncertain. According to the first reports of the Chinese, her captain, who had several times disregarded the Admiral's signals, deliberately steamed out of line, rammed and sank a Japanese ship, and in so doing received such injuries to his own ship that she also went down. This is very doubtful, for the Japanese official reports make no mention of any of their ships being rammed, and it is certain none of them was sunk. The earlier reports mentioned a second armed merchantman, besides the Saikyo Maru, and it has been conjectured that this might have been the ship sunk. It is much more probable that no such ship was present. The later Chinese reports say the Chih Yuen was sunk by gun fire, and went down bow first, screws revolving.

At half past three, when the two flagships were in close range, the Matsushima's turret was struck by a 12″ shell, which did great damage and set the deck on fire, though apparently it did not penetrate the armor. Another shell exploded aboard the Matsushima, dismounting the forward 4.7″ rapid-fire gun and killing a number of men. The gun was hurled violently across the ship. The Japanese flagship had been from the first the object of the Chinese' special attentions; her commander and first lieutenant were killed, 120 men either killed or wounded. Admiral Ito then, like Commodore Perry at Lake Erie, transferred his flag to the Hasidate.

About this time—3.30 p. m.—it is reported that firing ceased on both sides, many of the ships, especially the Chinese, being on fire. The action recommenced at about 4.30, by the five ships of the Japanese main division again attacking the two Chinese battleships. Firing finally ceased at six.

The whereabouts of the Hiyei and Saikyo Maru were then uncertain. The former, on fire, had retired as already described. A torpedo fired at her missed. She suffered severely from shells, and one exploding in the officers' quarters killed two surgeons, several nurses, and many men already wounded. The fire was finally got under control. She went to the rendezvous and removed her wounded to a transport next morning, then sailed in company with the Kaimon to the scene of the battle, at which the latter had not been present, and returned to rejoin the fleet on the 20th.

The Saikyo had also taken some part in the fight and got roughly handled. She first opened fire at long range, and later got to close quarters with the Chinese ironclads. After an hour or more her steering gear was disabled and she retired, attacked or chased for awhile by the Ping Yuen and one of the smaller Chinese vessels and two or three torpedo-boats. Two torpedoes were fired at her and missed, one of which, discharged from a distance of 40 or 50 yards, passed under her bottom. The Saikyo returned to the rendezvous early the following morning.

Falling darkness ended the battle. Admiral Ting gathered the remnants of his fleet and steered—as afterwards appeared—for Port Arthur. Admiral Ito recalled his van division and shaped a course supposed to be parallel to that of the Chinese squadron, which was standing to the southward, apparently for Wei-Hai-Wei. Speed was reduced to that of the slowest injured ships, and the fleet separated from the Chinese as a precaution against torpedo-boats. During the night, which was dark, the enemy was no longer in sight.

Admiral Ito steamed southward until dawn, hoping to intercept the Chinese off Wei-Hai-Wei. Not finding them, he ordered the Akagi to proceed to the rendezvous, returned with the rest of the fleet to the scene of the action, and there discovered the Yang Wei, beached and deserted. The Chiyoda blew her up with a torpedo,—the only one fired by the Japanese. Thence the fleet went to the rendezvous or "temporary anchorage," where it arrived early on the morning of the 19th, found the Akagi and Saikyo Maru, and next morning was joined by the Hiyei and Kaimon.

Later reports state that the Kuang Ki, having made her escape early in the battle, after the chase of the Akagi, ran on the rocks in Talien Wan while making for Port Arthur. There she was discovered, apparently some days later, by the Naniwa and Akitsushima; and her crew, seeing the cruisers, set fire to her and fled. The Japanese completed her destruction.

By the latest accounts the Chinese lost five ships, and at least two others were disabled. The Chao Yung, King Yuen and Chih Yuen were sunk; the Yang Wei and Kuang Ki were run ashore and subsequently destroyed. The Chen Yuen and Lai Yuen were totally disabled.

The Ting Yuen is reported to have been struck by no fewer than 200 projectiles, but her armor was not seriously damaged. The deepest dents were about three inches. Her upper deck was entirely destroyed by fire; two of the secondary battery guns were disabled; all the signal halliards were shot away; but the engines were uninjured. The Chen Yuen was hit fewer times—120—but her injuries were even more serious than the flagship's. Her main battery was crippled; she is reported to have reached the anchorage almost sinking, about three feet down by the head. The Lai Yuen suffered most from fire. She was gutted fore and aft; the deck and bulkheads about the magazine became red hot. The Ping Yuen, according to Admiral Ito's report, suffered severely from fire; according to others she took little part in the action. The Ching Yuen also is reported to have been badly hulled.

Of the entire fleet only three—not counting the Ping Yuen—escaped without very serious injury,—namely, the Ching Yuen, Chi Yuen and Kuang Ting. And of these three, two—the last named—had run away; as did at least one other. The captains of the Chi Yuen and Kuang Ki have since, in consequence, been beheaded.

As for the Japanese, three ships—the Matsushima, Hiyei and Akagi—and also the Saikyo Maru, were more or less severely injured; and of these the two small ships and the armed transport were driven out of action. All the rest were injured very slightly or not at all. The Yoshino, in coming to the rescue of the Hiyei and Akagi, was struck several times and sustained some damage to one of her forward sponsons, which was repaired on the spot. The Matsushima had to be sent to Japan; the others were repaired by their own hands.

With regard to the loss of life, there is the same appalling inequality. The Chinese casualties are variously stated, from 700 killed and 250 wounded, to 1500 altogether, including the men lost in the ships sunk. Several of the foreigners serving in the Chinese fleet were killed. The Japanese loss, according to the highest figures in any of the reports, was 10 officers and 84 men

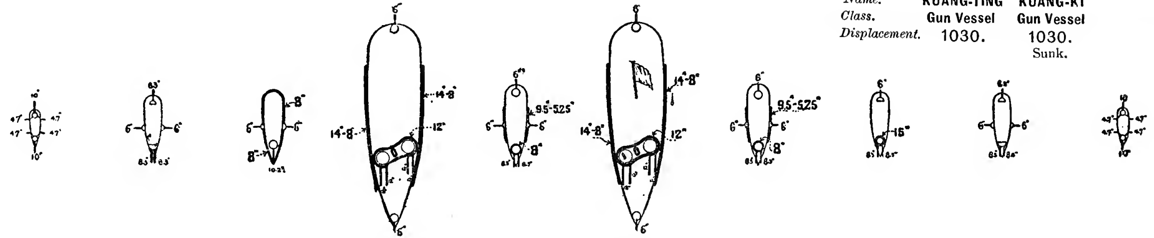
COMPARISON OF VESSELS ENGAGED.

BATTLE OFF YALU RIVER, SEPT. 17, 1894.

TORPEDO BOATS.

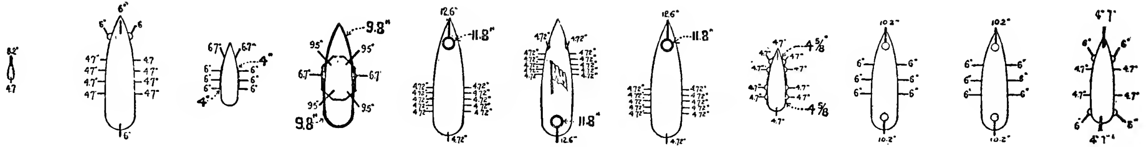
4.7"
4.7"
4.7"
4.7"
4.7"
4.7"

	k	*l*
Name.	**KUANG-TING**	**KUANG-KI**
Class.	**Gun Vessel**	**Gun Vessel**
Displacement.	1030.	1030. Sunk.



	j	*h*	*e*	*a*	*d*	*b*	*c*	*f*	*g*	*i*
Name.	**CHAO YUNG**	**CHING YUEN**	**PING YUEN**	**CHEN YUEN**	**LAI YUEN**	**TING YUEN**	**KING YUEN**	**CHI YUEN**	**CHIH YUEN**	**YANG WEI**
Class.	**Gun Vessel**	**Protected Cruiser**	**Coast Defense Vessel**	**Battle Ship**	**Coast Defense Vessel**	**Battle Ship**	**Coast Defense Vessel**	**Coast Defense Vessel**	**Protected Cruiser**	**Gun Vessel**
Displacement.	1350. Sunk.	2300.	2600. Injured. (?)	7430. Disabled.	2900. Disabled.	7430. Badly injured.	2900. Sunk.	2355.	2300. Sunk.	1350. Sunk.

CHINESE FLEET.



	11	9	6	4	2	1	3	5	7	8	10
Name.	**AKAGI**	**YOSHINO**	**HIYEI**	**FUSO**	**ITSUKUSHIMA**	**MATSUSHIMA**	**HASIDATE**	**CHIYODA**	**NANIWA**	**TAKACHIHO**	**AKITSUSHIMA**
Class.	**Gun Vessel**	**Protected Cruiser**	**Armored Cruiser**	**Armored Cruiser**	**Coast Defense Vessel**	**Coast Defense Vessel**	**Coast Defense Vessel**	**Armored Cruiser**	**Protected Cruiser**	**Protected Cruiser**	**Protected Cruiser**
Displacement.	614. Injured.	4150.	2250. Injured.	3710.	4280.	4280. Badly Injured.	4280.	2250.	3650.	3650.	3150.

JAPANESE FLEET.

killed, and 160 officers and men wounded,—total 254. The greatest loss was aboard the flagship Matsushima.

Such were the incidents of this memorable battle, as far as the truth can be made out from the mass of incomplete and conflicting reports thus far published. Many criticisms of it have been written, opinions the most various and opposite expressed, and scarcely a theory of naval tactics or construction has not been held to have been either proved or disproved by it. In the humble opinion of the present writer, the moral of the tale is very plain.

With regard to construction, the most striking and important lesson undoubtedly is the liability of modern ships to injury from fire. Throughout the whole engagement conflagrations were raging, and the severest damage to both fleets was done by fire. It may be supposed that the Chinese, at least, made no efficient efforts to put out the flames ; but still the warning is unmistakable that men-of-war ought, if possible, to be built entirely of incombustible materials.

As to the relative advantages of different types of ship, this battle certainly did not prove that unarmored cruisers can stand up against battleships,—Lord Armstrong, the builder of the Piemonte, to the contrary notwithstanding. Rather quite the contrary, it proved, if it proved anything at all about the question, that heavy guns are necessary to attack heavy armor. Witness the battering of the Ting Yuen. It may be replied that the Chen Yuen's heavy guns were disabled by a single shot. The answer is not that she would have been better off without them in an action with another armored ship, but that heavy guns must be heavily protected. There is hardly a modern battleship afloat with her heavy guns so badly mounted, and without, in addition, a numerous secondary battery powerful enough to have silenced the Matsushima or Chiyoda. What this action did show regarding types is how much a fleet is handicapped by being composed of dissimilar ships. Even one or two discordant units, like the Akagi or Yang Wei, may cripple a line-of-battle.

It is to be regretted that the tactics of the battle are so imperfectly described. Enough is known however to justify certain broad conclusions. Admiral Ito, realizing his superiority in ordnance, wisely neglected his torpedoes and his rams, and formed his line-of-battle in the way to reap the fullest advantage from his guns. Until more precise knowledge is available it is probably premature to say that the Japanese superiority in speed absolutely prevented the Chinese from closing to ram. But this much at least is certain, that if modern fleets are to follow the tactics of the Athenian triremes, it is absolutely essential that ships must move and turn in unison. The ridiculous performances of the Chinese torpedo-boats will not discourage the advocates of those auxiliaries in fleet actions. In the words of M. Weyl, "In skillful hands the torpedo sometimes misses; managed by Chinese, it is absolutely inoffensive."

All accounts of the damage suffered by the different ships go to show the tremendously destructive power of modern ordnance. It is worth noting that the Chinese reported that they suffered most from the small-caliber rapid-fire guns. This probably refers to injury to personnel. In gun practice as in ordnance the Japanese were far superior to their enemies. In the latter part of the battle the Chinese ships ran short of ammunition. The two ironclads fired 197 rounds from their 12″ guns. We cannot tell from this precisely what the time between fires was, because the duration of the action is not exactly known, nor the time when the Chen Yuen's heavy guns were disabled, but it was probably from 5 to 6 minutes. If any deductions regarding weapons can be drawn from a battle between antagonists so unequal, they verify the predictions of Professor Alger: "A ship which, either improperly armed or manned with men insufficiently trained in gun practice, trusts to her torpedoes or ram and endeavors by them to gain the victory, will fall an easy prey to an antagonist in whose construction and tactics the gun is recognized as the paramount weapon." And, further, "power lies in broadside far more than in end fire."

We are not told what signals were made. The only ones mentioned in the Japanese reports were made before the action began, and after it had ended. On the Chinese side we hear of one captain repeatedly disregarding the admiral's signals, and of all the signal halliards being shot away. All accounts describe the ships of the Celestial Empire disordered and disorganized from the very first, the fleet of the Rising Sun manœuvring throughout with admirable precision.

In his conception of grand tactics, Admiral Ito proved himself immeasurably superior to the Mandarin who before this battle had the reputation of an able admiral. It is impossible not to admire the mastery of the art he displayed, while at the same time one wishes he had had a foeman worthier of his steel. Admiral Ito's plan of battle appears to have been prearranged. In the words of the official report, "our fleet manœuvred so as to concentrate its fire on one flank of the Chinese squadron, then on the other." But whether preconcerted, or the inspiration of the moment, his plan to double on the weakest part of the enemy's line, in a manner virtually identical with that of Nelson at the Nile, was an application of the unchanging principles by which all battles have been won. It is very much to be doubted, on the other hand, whether Admiral Ting had any preconceived plan of action whatever. By his miserable formation he laid himself open to be beaten in detail. Had the Chinese fleet been capable of concerted movement, it is conceivable that by forming column, by "vessels right turn," before the Japanese van had passed around its wing, it might have frustrated Admiral Ito's plan and concentrated all its fires upon the head of the enemy's advancing column. Even after his flank had been turned, a bolder leader would have seized the opportunity to separate the two divisions of the Japanese fleet.

Not a little of the glory of the victory belongs to Admiral Teuboi, the second in command,—or to the captain of the Yoshino, whichever it was,—who with *coup d'oeil* worthy of Nelson at Cape St. Vincent, without waiting for orders, led the van away from the prescribed course to carry succor to the Hiyei and Akagi. If he did not actually save the day, at least he saved those two ships.

And "the conduct of our crews was above all praise." The commander-in-chief concludes his official report by saying: "One thing to be specially noted is that even the seamen, firemen and others—of course it is unnecessary to speak of the officers—discharged their duties with evident satisfaction, and preserved their presence of mind even when the enemy's fire was at its hottest and when their superiors and comrades were falling dead or wounded beside them. On this point there is remarkable unanimity among the reports of the various commanding officers." On the other side, what a contrast! Admiral Ting was as ill-supported as old Benbow. He is said to have conducted himself with "admirable coolness," but his fleet acted like a scared flock. The shepherd knew not his sheep, and the sheep knew not their shepherd. Ship after ship under the yellow dragon fled toward the shore. Two captains have lost their heads for cowardice. The gunners of the King Yuen alone relieve the dismal story. Bravely indeed they fought, with the savage courage of despair, when no hope remained of either victory or flight.

If there is any criticism to be made of Admiral Ito, it is that he did not continue the battle to the bitter end. He had eight ships in fighting trim, while at the most five only remained of the Chinese fleet, and two of those were disabled. "Had we taken ten sail, and allowed the eleventh to escape, being able to get at her, I could never have called it well done." It is remarkable that not a single ship surrendered. Every one of the Chinese fleet either was sunk, or took to flight, or retired after the battle was over. The two battleships, the mainstay of the enemy's strength afloat, were still unconquered, and the demoralization of the Chinese, which Admiral Ito had witnessed, might have emboldened him to take greater risks. And it certainly was a blunder to lose touch with the enemy during the night. His apprehension of the Chinese torpedo-boats, which is the reason given, certainly was not justified by the experience he had had of them that day.

But this suggestion that Admiral Ito, having done well, might have done better still, is made with extreme deference. It must be borne in mind that we have as yet very imperfect knowledge of the operations of the war, and none whatever of the orders under which the admiral was acting. It may well be that Captain Mahan's comment upon the battle of Cape St. Vincent is perfectly applicable to the Yalu: "It has been thought that further pursuit of a fleet so disgracefully beaten would have increased the British triumph; but Jervis was not the man to risk a substantial success, securely held, for a doubtful further gain. The victory essential to Great Britain was won; the worthlessness of the Spanish navy was revealed,—it could no longer be counted a factor in the political situation. In the opinion of the author, Jervis was right not to expose this, the great and attained result of Valentine's Day, to those chances of mishap that cannot be excluded from the operations of war."

Upon Admiral Ting the following judgment, severe but just, has been written by M. Weyl: "Voilà des années qu'il commande la flotte de Petchili, et il n'a pas su constituer une force navale digne de ce nom! . . . Des mouvements de l'ennemi il ne savait rien, et s'il s'en inquiétait, c'était d'une façon toute platonique! L'amiral Ting s'est bravement conduit, mais le courage ne suffit pas à ceux qui ont le redoutable honneur de commander en chef."

Any discussion of the strategy of the campaign belongs rather to the history of the war than to the story of a single battle. It may be remarked however, that whatever knowledge of strategy Admiral Ting may have had, he was bound hand and foot by the orders of the Tsung-Li Yamen. He is not the first admiral that has suffered from the meddling of cabinets. The same thing may be true of Admiral Ito. Otherwise the question arises: Would he not have rendered more effectual service by blockading the Chinese fleet and transports in Port Arthur and Talien Wan, after the manner of St. Vincent before Brest, than by guarding the flank of the army in the Ping Yang inlet? Once free, however, he moved with no uncertain steps and manifested an energy and forethought in bright contrast to the lethargy or indifference of Admiral Ting.

The battle of the Yalu, like the frigate actions of 1812, was won by the stronger fleet; but the loss inflicted was out of all proportion to the preponderance of material force. As history has again and again proclaimed, battles are not won by ships and guns alone, but by cool heads, trained hands, steady nerves and brave hearts. And this is the lesson of the Yalu.

Ships and guns, the best of their kind, Admiral Ito had; and the mere provision of such a fleet—in no small measure due to the personal influence of the Emperor himself—shows on the part of the government the same foresight that has characterized all the operations of this war. And the ships themselves were well equipped,—as anyone that has seen them can bear witness; while the Chinese, to cite only one example from a letter by the American commander of the Chen Yuen, were "badly fitted out in the surgeon's department, only two Chinese doctors to 20 ships and an army of 300,000 men." The Mikado's sailors kept their lamps trimmed and were ready when the bridegroom came; while the subjects of the Son of Heaven, like foolish virgins, had let their oil run dry, and the crisis found them unprepared.

But not only was the Japanese fleet in a state of high efficiency; the personnel of every rank, by previous energetic training and hard study, was prepared for the day of battle. And when the great day came, the squadrons of evolution, which the Japanese have had ever since they have had a fleet, the naval manœuvres, which they have carried on for the last two or three years for periods of a month at a time, the study of naval tactics and the conduct of war, in which the admirals and captains took such pride,—all bore their just fruit. Can anyone doubt that, whichever fleet Admiral Ito and his captains and crews had fought, they would have won?

This Asiatic war, waged between two nations whom we newer western civilizations have been accustomed to regard as barbarians, has such transcendent interest to us, not because the battle of the Yalu, the first modern fleet action since Lissa, has settled any moot questions of naval tactics or naval construction; but because it has furnished a most striking exemplification of the everlasting truth, which all history has proved,—that training, organization, discipline, ésprit de corps—these are the begetters of victory.

"The gods all things on men bestow, at labor's price."

One word more. It is ludicrous to note how the French rejoice that some of the Japanese ships were designed by them; how the Germans congratulate themselves that the Japanese regimental organization was modeled after theirs; how the English, who seemed at first to be not a little chagrined that their friends the Chinamen were getting so badly beaten, now pat themselves on the back because they had a share in building the Japanese fleet, and set the fashion in uniforms; how we Americans take unto ourselves credit that some of the Japanese officers were trained at the Naval Academy; how all we foreigners congratulate the Japanese on their progress in European civilization and skill in European warfare. Let us rather acknowledge them masters of the art. Ships and guns and uniforms, elementary training and drill-books, indeed, they had of us; but these, as the Japanese call the Roman alphabet, are but the "gateway to the kingdom of western knowledge." The principles of the art of war are catholic and eternal, and belong not to one nation nor to one age. The Japanese are a race of warriors and sailors, and trace back their martial inheritance from the long line of Shoguns, beginning with Yoritomo, and his brother who won the great sea fight near Shimonoseki seven centuries ago; from the famous Iyeyasu, first of the Tokugawa line; from the great general Hideyoshi, who invaded Korea three hundred years ago, and many more brave daimios and samurai who have made their names terrible in war, since the day when the first Mikado, Jimmu Tenno, descendant of the Sun-goddess, sailed up the Inland Sea.

DISCUSSION.

Lieutenant-Commander RICHARD WAINWRIGHT, U. S. N.:—The battle of the Yalu has been treated in a most satisfactory manner by Ensign Marble. He has arranged the data and adjusted the conflicting statements with skill and discrimination. I am glad he does not follow the plans of Lieutenant Miyaoka, I. J. N., who gives the distance between the divisions of the Japanese fleet, when advancing to the attack, as 4000 yards. From Mr. Marble's figure this distance appears to be about 1300 yards. This latter distance may be due to irregularity in formation; but it would be difficult to justify such a separation between divisions as 4000 yards with any tactical theory.

That the Japanese succeeded in doubling on the Chinese fleet is undoubted and according to Mr. Marble they doubled on the right flank of the Chinese fleet both in position and in succession. It is doubtful if this utilization of higher speed, which enabled them to double on the right wing in position but resulted in a further separation of the two divisions, would have been advisable against a more skillful enemy, but the doubling in succession was tactically sound.

The escape of the Hiyei and Akagi from total destruction, especially that of the former, which passed between the two battleships, illustrates the inefficient armament of the Chinese vessels. Had the battleships been properly armed with rapid-fire guns, and had they been decently served, the Hiyei must have been destroyed.

When the question of the Japanese fleet keeping in touch with that of the Chinese is considered, it must be remembered that the former fleet was composed of cruisers and that Admiral Ito would have been obliged to detach from his main fleet several of its units in order to maintain touch.

It would have been a questionable action for Admiral Ito, with only eight ships remaining, to have detached two or three of the eight to act as scouts. Had his fleet been one of battleships with a respectable allowance of cruisers, he would have been seriously in fault had he failed to keep touch with the Chinese.

The criticism of Admiral Ito for guarding the flank of the army in the Ping Yang inlet, in place of blockading the Chinese fleet in Port Arthur and Talien Wan, hardly seems well founded, and the comparison with Saint Vincent off Brest does not seem to be applicable to the condition of affairs immediately previous to the battle of the Yalu. Saint Vincent was guarding no specially weak point of his own forces. His object was to prevent the Brest fleet from engaging in any sea operations, particularly from combining with other French fleets. The escape of a few vessels was unimportant. As history shows is the correct practice, he drew the lines ot blockade close to the port. Ito had a specially weak point to guard, *viz.*, the transports that carried one portion of the army to Ping Yang, and the supply boats for the entire army. Even had the Japanese been of sufficient strength to blockade successfully the Chinese fleet, it would have been necessary to leave a guard of several vessels at the inlet in case of the escape of a small portion of the Chinese fleet. Then the eleven vessels of the Japanese were not a sufficient force to blockade the twelve Chinese vessels.

Where a whole coast or a great commerce must be protected from a fleet, it is sound strategy to blockade closely that fleet, for there being many weak points it is impracticable to guard all; but where there is one weak point it can be protected best by holding the force at or near the point. It was not sound strategically, landing a force with the Chinese force united, unbeaten and free to take the sea; of this history gives many illustrations; but one of the most frequent incidents in history shows the necessity of running risks in war and attempting undertakings, which, while not strictly correct according to the maxims of strategy, are justified by the governing conditions. Japan could not afford to arrest her advance upon the Korean frontier until her fleet was able to bring the Chinese fleet to action and defeat it. Admiral Ito felt strong enough to drive this fleet back and prevent them from disturbing the operations of the army.

The danger from a flanking fleet should not be exaggerated. It is most dangerous when the co-operating fleet is transporting troops, assisting with its guns, or otherwise hampered by the nature of the operations; then the attack of a flanking fleet is to be dreaded; but when all the troops are in transports, the landing is unopposed and the co-operating fleet untrammeled except by the obligation of a complete defense, the attack of an inferior or equal flanking fleet becomes an ordinary incident of war, the liability being no greater than usual although the consequences of defeat might be far more serious.

Lieutenant W. F. HALSEY, U. S. N.:*—Ensign Marble's most ably written article on the Yalu river fight has been read with great interest; but an intelligent criticism on its contents is impracticable. With the advantages to be gained by reading numerous reports of the engagement, coupled with conversations with officers of both sides that were engaged in the fight, and after seeing some of the injured vessels, there still remain so many conflicting conditions that a report compiled from newspaper descriptions must necessarily contain numerous inaccuracies. From information received on the station, some of the doubtful points under discussion may be made clearer, but an absolutely accurate description of the naval battle of Hiyang (Yalu) is yet to be written. The relative sizes of the two fleets as to tonnage, guns, and armor is practically established.

As a unit the speed of the Japanese fleet did not exceed 10 knots; for though the Akagi is quoted as a 12-knot vessel, 10 knots represented the best results from that gunboat under most favorable conditions. Individual ships of the Japanese were very fast, notably the Yoshino. The writer has seen this vessel make 19 knots with ease, when chasing torpedo-boats that had escaped from Wei-hai-wei. The formation of the Chinese fleet was that of an irregular double echelon on the battleships Ting Yuen and Chen Yuen in the center. The Japanese were practically in column of vessels, but the flying squadron, composed of the Yoshino, Takachiho, Akitsushima and Naniwa, was separated from the main squadron by a distance much greater than that between individual vessels. When the Chinese fleet was first sighted, the vessels of Japan were headed for the center of their antagonist's formation. Admiral Ito changed course so that the head of column was directed towards the right wing of the enemy. The speed of the flying squadron was increased to 10 knots, and when they opened fire the guns were apparently concentrated on the two vessels on the extreme right wing of the Chinese. These two, the Chao Yung and Yang Wei, were first set on fire, and before very long went down. The Akagi, on account of slow speed, and the Sakyo, being in no sense a man-of-war, had taken positions to the left of the main squadron. The flying squadron after inflicting the injuries to the two Chinese vessels, mentioned before, turned to starboard at a distance of about 1600 meters from the Chinese fleet. This squadron was signaled to join the main squadron and began turning to port behind the other fleet. Before this evolution was completed the Hiyei and Akagi had gotten into difficulties, and Admiral Ito made a second signal for the flying squadron to go to the assistance of the smaller vessels. Apparently the shortest way to reach the scene was by continuing the circle, and this accounts for the two turns made by the flying squadron, the explanation of which we were unable to obtain for some time. There are no other reports of any signals having been made by the Commander-in-Chief to the Japanese fleet during the action. As

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* Secretary to Commander-in-Chief, Asiatic Station.

the evolutions were performed in good shape by the flying squadron, it is but fair to suppose that the signals were thoroughly understood. The main Japanese squadron advanced to the attack, and the Chinese fleet turned so that their vessels were nearly bows on. Firing at this time became general, the Chinese fire being more rapid (with the large caliber guns), and at the same time very wild. The Hiyei being unable to maintain the speed indicated (10 knots) fell behind the main squadron, and as the latter turned to starboard behind the Chinese fleet, the Hiyei was closed upon by the Chinese vessels. At a distance of about 700 meters the Ting Yuen and Chen Yuen failed to inflict serious damage upon the Hiyei; the latter vessel was set on fire and hauled out of the action. The Chinese had lost all formation as regards distances between ships, and the captain of the Hiyei, fearing to be rammed by one of the battleships if he continued to follow the main squadron, boldly steered his vessel between the two large ships; it was a nervy piece of work, but most successfully executed, and probably saved the ship from utter destruction. The Hiyei subsequently joined the main squadron.

The Akagi also was unable to keep up with the main squadron, and found herself the object of attack from the left wing of the Chinese fleet. The little gunboat was well fought, and finally succeeded in getting away, though roughly handled. The captain was killed on the bridge: a 15-cm. shell struck the pedestal of the bridge gun, glanced and brought up on an iron brace; the shell broke (did not explode) and a fragment killed the captain. The executive officer was shortly afterwards wounded on the bridge, and his place was taken by the navigator, who kept command until the wounds of the executive were dressed, when the latter again assumed charge. The mainmast was shot away, but no one was injured by the fall, for the only top gun that was manned was in the foretop. The maintop was not occupied when the mast fell. On the Akagi, 11 were killed, including the commanding officer, and 17 wounded. In addition to the loss of the mainmast, there were two 15-cm. shells passed through the ship above water, a 3-pdr. shell went through the shield of the stern gun, the top and bridge guns were disabled. It seems a miracle that this small vessel was not blown off the face of the waters. Considering the number and size of the Chinese ships, the short range, and the length of time under fire, the damage done the Akagi was comparatively slight. The accuracy of the Chinese fire in this case is not apparent; it is stated that the sight-bars were never changed after being set for the first range. The main squadron was now circling the Chinese fleet and was joined by the flying squadron, the Yoshino and Matsushima approaching bows on so that the Chinese fleet was surrounded. The Japanese apparently devoted their fire to the battleships, encircling the fleet and increasing the diameters of the circles as they neared the armored vessels, and decreasing the circles as they left them. The Chinese were huddled in the vortex of this fire; stunned by the volume of projectiles poured upon them, they were without instructions and were out-fought. The Chinese commanders of the smaller vessels sought safety in flight. Sullenly the two battleships held their ground, but their case, under the existing conditions, was hopeless. The Ting Yuen took fire, but was ably protected by her sister ship, the Chen Yuen. The handling of this last named vessel has been complimented in more than one report from the Japanese. Incidentally, it may be remarked that the only American in the fight was on the Chen Yuen ; his rank was that of commander, and his duties were to advise the Chinese commanding officer. This American was graduated from the United States Naval Academy.* The Tsi Yuen, Lai Yuen and King Yuen were in active retreat, and in pursuit of these went the flying squadron. The Lai Yuen caught fire, and the Yoshino and Takachiho followed the fleeing King Yuen. Here we find a discrepancy in regard to the fate of this vessel, or rather the cause of her sinking. The first Japanese reports called attention to the fact that this belted cruiser caught fire and went down, being injured by the 15-cm. Q. F. guns of the Yoshino, fired at a distance of 1800 meters. Officers of the Yoshino have made the same statement, and will show, with pride, the gun that they claim did the work. From another officer that was temporarily on board the Yoshino, it was learned that the vessels had approached to within about 800 meters when the Yoshino was preparing to discharge a torpedo. Before the torpedo could be fired the King Yuen listed to starboard, two fires broke out, the stern became submerged, and after a violent explosion on board, probably the bursting of the boilers, the ill-fated vessel disappeared. As the Takachiho was firing at the same time, it seems more probable that the 10-inch guns of this vessel inflicted the mortal wounds. The Japanese still kept up their fire on the two iron-clads, while the latter were slowly making their way in the direction of Port Arthur. The fight ceased before sundown ; pursuit not being kept up by the Japanese ships. The remnant of the Chinese fleet succeeded in reaching Port Arthur.

Three torpedoes were fired during the action, and all from the largest of the Chinese torpedo-boats. This boat, with the lieutenant in command, was fallen in with on the first visit of the Baltimore to Port Arthur, before its capture by the Japanese. The lieutenant in command had been ten years in the United States, principally at New Haven, his English was without a flaw, and consequently his narrative was clearly understood. The sea was smooth, not rough as quoted by Mr. Marble, and the conditions were good for torpedo work. The Sakyo after being roughly handled, steam steering gear disabled, had connected hand gear, and at top speed was getting away from close quarters ; the Chinese torpedo-boat was speeding in the opposite direction, and under these conditions the vessels approached. Each manœuvred to keep end on ; the Sakyo used the machine guns, and the torpedo-boat discharged from the bow first one

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*Commander P. N. McGiffin, I. C. N.

and then a second torpedo; both missed. At a distance of 30 meters the third torpedo was launched from turn-table on deck, broadside, at the Sakyo; the torpedo was set for 4½ meters, the Sakyo drew 18 feet, but the short distance between target and torpedo-boat proved the salvation of the former. Before the torpedo had recovered from the initial dive, it had passed under the Sakyo and broached harmlessly on the other side. In the words of the Chinese lieutenant, "It was a golden opportunity, and I missed." The vessels parted company, neither being the least injured in the encounter. There is every reason for believing that the Chinese lieutenant was perfectly up in his work, he was under fire all the time, and yet handled his boat with coolness; the torpedo simply failed to score.

It has never been understood on the station that the large guns of the Chen Yuen were hurt in the least; the information that they were damaged by the fire of the Japanese is an error I think, for having listened to a partial account of the fight given by the American on board the Chen Yuen, the impression received was to the effect that the guns were as serviceable after the action as before; the proper kind of ammunition in the shape of common shell was lacking on the Chinese battleships, and when the fight ended the supply of such shells as were furnished was very short.

Facts that were well known have been accentuated in this engagement. The Japanese took the risk of piling up rapid-fire ammunition on deck in order that the supply might be ample; a shell from one of the 30.2-cm. guns of the Chen Yuen exploded over this pile on the Matsushima, and in turn caused an explosion of the individual projectiles; eighty persons were killed or wounded, the vessel was set on fire, and the large gun put out of action.

On this vessel two shells, one a 6-pdr., exploded in the cofferdam above water, pieces of the shells being found embedded in the cellulose. No damage resulted from these wounds, and as they were all above water, no data is obtained as to the value of cellulose for obturating purposes. The total killed on the Japanese side has been variously given, probably the number will not exceed 100, of which ten were officers. The damages done to the ships were not great, the Akagi, Hiyei, and Matsushima suffering the most, but even these were not seriously damaged. On the Chinese side we find the Chao Yung sunk, the Yang Wei stranded, Chih Yuen sunk, King Yuen sunk, and the Kwang Chia, while fleeing, struck on a shoal outside Talien Wan, and was destroyed. Of the other ships none were badly injured except by fire; hulls and motive power did not suffer, but superstructures and upper decks were simply wrecked by the rapid-fire guns of the Japanese. The Chen Yuen was on fire several times. All the Chinese vessels that were sunk had taken fire. About 600 went down on the Chinese ships, while 100 in addition were either killed or wounded on the Chinese side. To prevent injury by splinters all the boats from the Chinese ships had been left at Port Arthur, one boat being the allowance for each vessel. The Japanese covered their boats with canvas well wrapped in. On the Chen Yuen, the hose had been led out and water was circulating through them, this being done to prevent unnecessary orders to the engine room in regard to pumps.

The Japanese fleet was officered and manned entirely by natives; their ships individually and collectively were well handled and fought; while the usual dash and nerve, so characteristic of the Japanese nation, was apparent everywhere. From seven to nine foreign officers of military education were on board the vessels that composed the Chinese fleet. These officers were of German, American and English nationalities. Apathetically the Chinese let fires burn that could easily have been put out in the first instance with but little damage. The shells in many instances were improperly fuzed. A naval fight lasting five or more hours took place, with a smooth sea, between two fleets equipped with the most modern appliances of destructive warfare. For the sake of comparison alone it is to be regretted that the fleets were not equipped with men of like characteristics. The result, if such conditions had obtained, would be merely hypothetical. The Japanese not only have learned well the lesson of civilization, but also have gone beyond and have become masters in the art of handling and fighting ships. Their bravery was never a subject for doubt. In this fight we find skill, nerve and ability, with the faster but weaker ships, pitted against the more powerful instruments in the hands of ignorant, apathetic and not over-brave workmen. The question of tactics does not require much discussion. With the Chinese there were none. Admiral Ito started well with his column of vessels; he cornered his quarry and nothing was clearer than that by encircling them he could inflict the death blow. Human beings could not exist in the terrific storm of projectiles that riddled the superstructure of the Ting Yuen and Chen Yuen; no signal halliards remained with which to signal, consequently each individual Chinese captain was left to shift for himself; they displayed greater ability in getting out of action, than in encountering their opponents. The ram was not brought into play, for the faster Japanese ships gave the Chinese no chance for this work; and naturally while the guns were doing such good work, it would have been folly to have rammed with the lighter vessels. The actual resistance of armor was not demonstrated by the Yalu river fight, for the Japanese hardly approached the battleship closer than 3000 meters, and at this distance the 14-inch armor of the Chinese was impregnable. The moral effect of the battleship was beyond question, for these two representatives of that class of vessel stood off the Japanese fleet. The battle was not won so long as they were able to hold their own; had the range been less the story might have been different. The Chinese were confused by the volume of projectiles poured upon the battleships and withdrew. These two vessels were able to continue the action, and with well disciplined crews, properly officered, would have done so. The danger from fire impresses one with the belief that wood work should be reduced to a minimum; though fires were frequent, the reports were perhaps much exaggerated. The Chinese were confident of success and underrated their opponents. Whether these impressions were fostered by their foreign instructors is not known. The meeting of the two fleets was accidental; for had Admiral Ito known of the vicinity of the Chinese he never would have sent his torpedo boats up the Taitong river. From reliable sources it is learned that if Admiral Ting had known that the Japanese fleet was in the vicinity there would have been no battle. Admiral Ting was caught in a trap, and being unable to escape, accepted the alternative and fought with disastrous results.

Assistant Constructor Y. WADAGAKI, I. J. N.:*—The subject of the paper is a most important one, and one to which a great many people have given their attention. While I do not feel myself competent to express any opinion on the subject, I hope it may be of some use to corroborate the truth of what the writer says, and to call attention to some slight misunderstanding which he seems to entertain. After carefully looking through the paper, one cannot but admire the intellectual ability of the writer who has succeeded in the difficult task of showing the real character of this great naval battle from utterly contradictory reports of various newspapers. The writer is quite right in stating that the battle was fought in the open sea, and not, as is often reported by news correspondents, at the mouth of the Yalu river. True, the Chinese had previously been engaged in convoying the transports of troops. So had been the Japanese. But, at the time of the encounter, neither party had encumbrance of any sort. In fact, the fighting commenced on equal footing, so far as the relative positions of the two opposing fleets were concerned.

The intention of the Chinese admiral seems to have been to get his vessels arranged in line abreast, as they had their guns more strongly developed at the bow than on the broadsides. Admiral Ito's masterly plan of circling round the enemy's fleet and concentrating all his available forces on its weak point from front and rear proved most successful. Due credit must be accorded to the captain of the Hiyei, who, seeing that his ship could not steam fast enough to keep up her position with the rest of the column, boldly broke through the Chinese line and was thus able to destroy its formation. The little Akagi also did good work. Indeed, it is not too much to say that the ability of the admiral, the patriotic devotion of the officers and men, and their training and discipline did as much to decide the fate of the battle as the quality and strength of the vessels themselves.

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*Navy Yard, Yokosuka, Japan,

Asking the reason why the Japanese did not continue the battle and push close after the Chinese to the bitter end, the writer of the paper expresses his opinion that Admiral Ito's apprehension of the Chinese torpedo-boats was not justified by the experience he had had of them that day. On this point I am rather inclined to think otherwise. What a torpedo-boat fails to do in the broad daylight she may accomplish with great success under cover of darkness.

Therefore, the Japanese admiral was perfectly right in not risking his ships in an uncertain attempt to complete the victory he had already gained for all practical purposes. He was warranted by the circumstances of that time to preserve his fleet intact in order to be able to proceed at any moment to execute much greater works, if called upon. With reference to the writer's suggestion that Admiral Ito might have done better if he had blockaded the Gulf of Pe-Chi-Li, etc., instead of guarding the coast of Corea, I will only ask him to remember the relative strength of the two contending navies. A fleet that undertakes to blockade the outlet of the enemy must have by far a superior strength. But such had not been the case with the Japanese Navy at the outset of the contest.

As regards the proposed change in the material for warship construction, although it is certain that most of the injuries received by the ships engaged resulted from conflagations, the idea of building the ships entirely of incombustible materials hardly looks practicable. Even if this were possible, what are we to do with the coal carried above the protective deck, which when set on fire would make the whole ship quite uninhabitable? It is therefore most desirable that every vessel of war should be provided with a fire main system arranged in as complete a manner as possible.

Lieutenant WILLIAM P. WHITE, U. S. N.:*—In a pamphlet entitled "The Naval Battle of Haiyang," compiled from official and other sources by Jukichi Inouye, appear reproductions of photographs taken on board the Saikyo Maru as she was withdrawing from action, about 3 P. M. In these the sea appears smooth, the trend of the smoke from different vessels indicating a breeze not stronger than moderate—ideal weather for target practice.

On inspection, Plate II seems to have been taken at the beginning of the fight, Plate III shortly after; still later the plate entitled "The Burning of the Chao Yung." In II, though the plate is not very sharp, the flying squadron is seen a thousand yards at least in advance of the main squadron, the Yoshino leading, Akitsushima third, Naniwa and Takachiho second and last—the vessels in pairs. The main squadron, Matsushima leading, Chiyoda second, Itsukushima and Hashidate third and fourth. Unmistakable are the three sister so-called coast defense vessels, the Matsushima having a high forecastle and her 32-cm. Canet gun on the main deck aft, while the other two have the gun forward and superstructure aft. The

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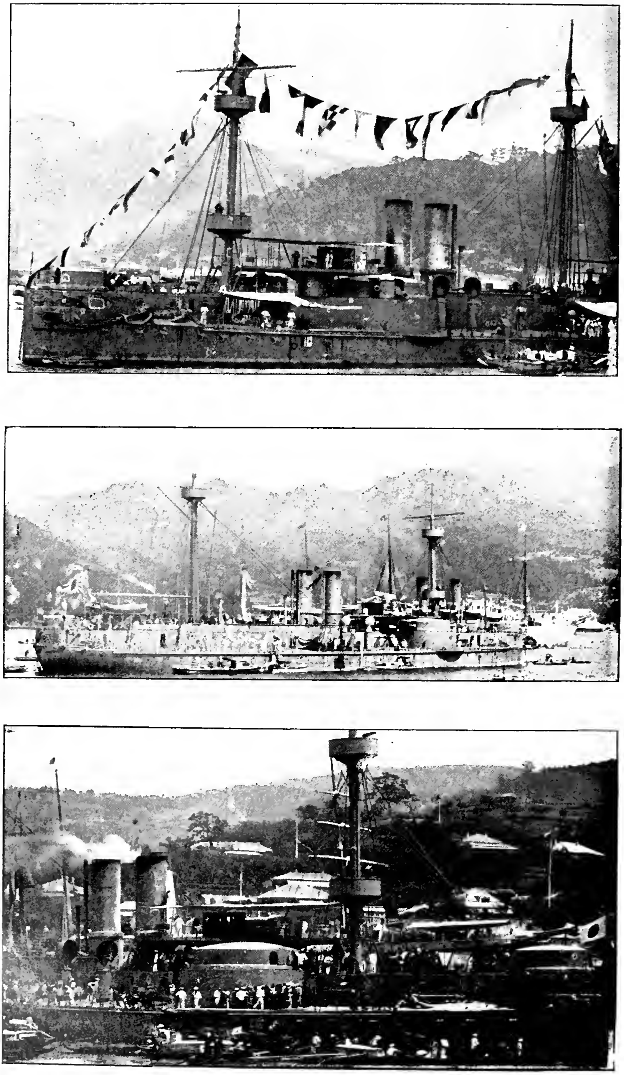
* U. S. S. Charleston, Asiatic Station.

Chinese fleet may be seen in the distance steaming almost bows on and that distance is very considerable. Owing to the arrangement of the Matsushima's battery, the line of battle must be approached at an oblique, this allowing the fleet attacking to maintain the distance as it could with its greater speed, without appearing to run away. The Japanese are said to have commenced the action at 3000 metres, and though decreasing it in regard to smaller Chinese vessels they seem to have maintained it in fighting the battleships.

The reason for attacking the right wing is evident, since the Chinese base lay in that direction; but apart from that, the arrangement of the battery of the Ting and Chen Yuen diagonally from starboard to port, if attacked on that flank, would strike the weakest point of these battleships.

The tactics of the Japanese fleet was then to clip the wing of the Chinese fleet, keep away from the battleships as much as possible and destroy him in detail. Inouye says the flying squadron changed course to port 16 points, and if they turned again 16 points to port they would still be able to bring their starboard batteries to bear on the Chinese fleet, and have it between two fires should the admiral see fit to take his squadron around the right flank of the enemy. This method of moving in a circle was a usual one with the Japanese in maintaining position, and it would have the advantage in this case of giving the speedy flying squadron an opportunity to succor the weaker slower vessels of the column, permitting the admiral, unhampered, to change the direction of the attack. The Matsushima, though badly punished, remained as flagship until after the battle was finished, so Inouye says.

The experience of the Chinese in a former skirmish with Japanese vessels led them to strip their ships, leaving but one boat on board, clearing away all boat davits, etc. But there seems to have been no organized fire brigade, and the disastrous fires which occurred on board their ships should properly have been controlled. In the case of the Ting Yuen a slight fire that might have proved fatal to the ship was put out by the exertions of a European. At Wei-hai-wei, we saw both battleships and there were no evidences then of any considerable fire, though the wooden sheathing, inside the superstructure, was cut up by the projectiles that had passed through it, the shot holes through the skin having been patched. These shot holes appeared to have been made by the smaller rapid-fire guns, and nowhere did there appear marks that might have been made by a 32-cm. projectile, although three of these great guns had been brought to bear on them. The hood of the starboard pair of barbette guns was pierced, but the guns themselves were uninjured, and there appeared nothing that should have affected the port guns. The 6-in. gun in the hood on the bow of the Chen Yuen was disabled. But the damage to both the battleships was immaterial. They were running short of ammunition, and would not have been able to carry on the fight on that account alone.



THE CHEN YUEN AFTER HER CAPTURE. SHOWING OUTLINES OF THE PATCHES PLACED ON THE SIDES.

The Japanese did not strip their ships as the Chinese had done, but their vessels were struck so few times, the precaution seemed hardly necessary; so poor was the quality of Chinese marksmanship that only one of their largest ships had to go to a dock yard for repairs. It may be interesting to know that a table of distances using the Matsushima's mast head angle was found on the Ting Yuen.

As to torpedoes, eight Japanese cruisers with an average of 4 torpedo launching tubes or cars fired not one torpedo; the Chinese fleet was beaten by gun-fire alone. Ten Chinese vessels armed, it is supposed, with torpedoes were equally reticent in making use of them ; only the Chen Yuen is said to have fired them from her above-water tubes, as a precaution lest they be struck by gun-fire, and she bears the mark of a projectile close to her starboard forward above-water discharge, very dangerously near.

The presence of torpedo-boats, though they seem not to have been very enterprising, was sufficient to make the Japanese fleet withdraw before dark. It is reported that the electrical connections on board the Japanese fleet were so deranged that they could not use their search lights.

The Chinese fleet was so badly beaten however, that its battleships only went to sea once afterwards, and then to escape from one port to take refuge in another.

It would have been interesting to see what the Japanese torpedo-boats might have done had they been present at Yalu. Their work at Wei-hai-wei leads us to suppose their presence might have made a difference, the Chinese vessels being so poorly supplied with rapid-fire guns of the smaller calibers.

In the Chinese fleet there was not one medical officer ; there was one and only one European at Wei-hai-wei.

Lieutenant Sims reports a very complete fire bill on the Chen Yuen, that their hose was led out and pumps running when the ship went into action.

Inouye gives the order of ships : Japanese fleet—Yoshino, Takachiho, Akitsushima, Naniwa, flying squadron ; Matsushima, Chiyoda, Itsukushima, Hashidate, Hiyei, Fuso, main squadron, and the Akagi and Saikyo. Chinese fleet in line, right vessel Chao-Yung, then Yang-Wei, Lai-Yuen, King-Yuen, Ting-Yuen, Chen-Yuen, and Ching-Yuen, Kwang-Ping, Tsi-Yuen, Kwang-Chia and Ping-Yuen.

I see from Admiral Ito's remarks published in fragments in the *Japan Mail*, in the battle of the Yalu, that the flying squadron did turn to port ; he had *intended* they should go to starboard, doubling on the enemy's right wing. Also he attributes the great loss of some ships with the slight loss of others to the slowness of the Chinese fire, not being able to load fast enough to permit them to fire at *each* vessel as it came up.

The white marks shown in the accompanying photographs are outlines of the *patches* that were placed over the shot holes. The marks in the redoubt are slight indentations which might have been made by 4.7-in. shell.

Ensign MARBLE:—I wish first to express my thanks to the officers who have been kind enough to criticize this essay, especially to Lieutenant Halsey, for the trouble he has taken, profiting by the opportunities he had in serving on the Asiatic station of getting information at first hand, to correct several misstatements of fact and to give a detailed account of the action.

Since the battle of the Yalu was fought now more than a year has passed. Between the writing and publication of this paper more complete and accurate reports have appeared than were then available, the facts are now generally known, every phase of the action has been criticized, and the world has drawn its conclusions. Want of leisure prevents the fulfilment of my original intention to revise the foregoing description and make it as far as now possible a complete history of the battle. Moreover it is unnecessary, since this essay is no longer news. This reply therefore will be limited to correcting misstatements of fact in the original, supplying only the most important omissions, then to modifying or corroborating the conclusions drawn, and finally to answering some opinions expressed in this discussion and in other articles, with which I disagree.

The more important articles on the battle of the Yalu that have come to my notice since this essay was written are the following: The naval battle of Haiyang, compiled from official and other sources by Jukichi Inouye, published in Yokohama,—which contains several photographs taken during the action, the first battle-pictures, it is safe to say, absolutely true to life; Die Seeschlacht von Hai-yun-tau, Der Krieg um Korea bis zur Einnahme von Port Arthur, Folgerungen aus den japanisch-chinesischen Seekämpfen für Kriegsschiffbau und -Armirung, in the *Marine Rundschau* for February, March, and April, 1895,—which last contains very full and detailed tables of the injuries received by the several ships; several articles in the *Revista general de marina*, the *Rivista marittima*, the *Revue maritime et coloniale*, the *Marine française*, the *Yacht*, the *Army and Navy Gazette*, and other papers; the Naval War between China and Japan, by W. Laird Clowes, and Lessons from the War in the East, anonymous, in Brassey's *Naval Annual* for 1895; the report of Herr von Hanneken to Li-Hung-Chang; and last in time, but first in importance as the testimony of a responsible actor in the fight, the article by Commander McGiffin in the *Century* for August, with the review by Captain Mahan.

As for the place where the Chinese fleet was found, it appears that the chart published by the Intelligence Office, from which the one here given was copied, is inaccurate. The island of Talu is off the mouth of the Yalu river. The Chinese fleet was lying to the eastward of the island outside the bar, while the transports and several small craft had gone fifteen miles up the river.* The smoke of the Japanese fleet was sighted about 10

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* See Commander McGiffin's plan in the *Century*. The Japanese are said to have possessed accurate charts from their own surveys of the coast made two or three years before.

o'clock; the Chinese immediately got under way, and their smoke was sighted by the Japanese about 11.30.* The sea was smooth and the breeze light.

A few slight corrections ought to be made in the table of the main batteries of the Chinese ships, which however do not materially alter the comparison. According to Commander McGiffin, the King Yuen and Lai Yuen had each two 6″ guns instead of three, the Ping Yuen's heavy gun was 12.2″ inside of 10.2″, the Kuang Ki had three 6″ and four 5″ guns instead of three 4.7″, and the Kuang Ting's three 4.7″s were rapid-fire guns. There are also some differences in the secondary batteries, but the total number of guns is exactly the same as given in the table—120. Commander McGiffin's table of the armament of the Japanese fleet is inaccurate. He seems to have followed the error in Brassey in regard to the Akitsushima. It may be typographical errors that give the Chiyoda fourteen 4.7″ guns instead of 3 pdrs. (the 5″ should be 4.7″), and the Yoshino eighteen instead of eight 4.7″s. Brassey's *Naval Annual* for 1895, by the way, gives the Akitsushima her proper battery at last, but adopts the spelling *Akitsusu*, which is original at least. With regard to spelling it is worth noting that Commander McGiffin gives *Tsi Yuen*, and pronounces it *Tsee*. *Chih Yuen* is pronounced *Chee*. By the same authority the two smaller gunvessels ought to be *Kwang Ping* and *Kwan Chia*.

The actual speeds of the two fleets can now be stated with great probability of certainty. Commander McGiffin gives that of the Chinese as 6 knots (and estimates the Japanese as double theirs); all the Japanese accounts agree that the speed of their main squadron was 10 knots, and that of the van or flying squadron, at times 14. The speeds given in the tables in Commander McGiffin's article differ very little from the maximum trial speeds hereinbefore given. (The average of the Chinese fleet is six-tenths of a knot less, and that of the Japanese two-tenths more in Commander McGiffin's than in these tables.) But since Commander McGiffin states that the Chinese fleet went into action under forced draft, and that in the early part of the engagement it steamed at about 6 knots, and ascribes great advantage to the Japanese in their superiority of speed, it is fair to assume that the Chinese were doing their best, that as a whole they could not keep up any higher speed. The Japanese fleet, leaving out the Fuso, Hiyei, and Akagi, may perhaps have been able to go faster than it did. The greater superiority of the Japanese van must be borne in mind.

The much-disputed order of the Chinese fleet was in fact an indented line, the flank ships somewhat astern of their proper stations. At the beginning of the action there were ten ships in line; the Ping Yuen and Kuang Ting (Kwang Ping) joined later. The Lai Yuen (in Fig. 1.) ought to be in the right wing of the Chinese fleet next to her sister-ship the King Yuen; and the Kuang Ting (Kwang Ping) also, when she came up, joined

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* *Marine Rundschau*, February 1895.

that wing. The left wing therefore had originally fewer ships than the right, and the early flight of the Kuang Ki (Kwan Chia) and Chi (Tsi) Yuen left only one ship, the Chih Yuen, on the port hand of the flagship.

In respect to the circling of the Japanese van after it had passed the Chinese flank, the turn was undoubtedly made to port, and not to starboard as shown in the foregoing figures. My apologies are due to Lieutenant Miyaoka for disputing the accuracy of his description on insufficient grounds. The explanation is suggested by Lieutenant White. It may also be there was an error in translation in the report upon which these figures were based: there is often some confusion between port and starboard. Mr. Clowes' article, quoting another version of this same report, says the van, in going to the rescue of the Akagi and Hiyei, "attacked the enemy on the latter's port side," instead of "with their starboard broadsides." Admiral Ito, in a speech in Tokyo on June 30th last, gave the following account: *

"I ordered the first squadron to attack the right wing of the enemy and then to come in upon his rear, utilizing for this purpose the great speed of the vessels of the first squadron. . . . The enemy . . . concentrated his chief attack upon my principal squadron. I managed to keep as far away from him as possible, with a view to attacking him from both sides—front and rear—when the first squadron had got astern of him. A misunderstanding in the signaling took place at this point, however, and the first squadron turned its course in the opposite direction, and consequently the principal squadron had to change its course also" (to which side is not stated, but presumably to starboard).

It thus appears that Admiral Ito first intended to double the enemy's flank as represented in Fig. 2. In a speech nine months after the battle he says a misunderstanding of signals caused the flying squadron to turn to port. Several Japanese reports, written nearer the time, state, as Lieutenant Halsey says, that the flying squadron at that moment was signaled to rejoin the main squadron; in that case it would have to turn to port. However, the fact is certain. Commander McGiffin in conversation said that the Yoshino began to turn to port almost immediately after passing around the Chinese flank, and after turning sixteen points she was heading in the same direction as the Chinese line, which in the meanwhile was standing on. The whole van division had overtaken and repassed around the Chinese flank, firing their port broadsides, before the main squadron passed around for the first time. The main squadron having passed around, the Chinese right wing was between two fires.

It also appears that the rescue of the Hiyei and Akagi by the flying squadron was not done by Admiral Tsuboi's (not Teuboi) initiative, but in obedience to signal from the Commander-in-Chief. His credit is hardly less for the skill and promptness of the execution. To accomplish it the van squadron made a second complete circle with starboard helm.

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* Published in the *Japan Mail.*

The officer who succeeded Admiral Ting when he was wounded, was Commodore Liu Poo Chin, captain of the flagship.* Actually the chief command, in so far as any was exercised during the remainder of the battle, appears to have devolved upon Herr von Hanneken, who was nominally adviser to Admiral Ting, but who, in his report to the Viceroy, speaks of "the two vessels placed under my immediate command—the two armor-clads," and mentions the orders given to the fleet as emanating from himself—using the first person. Commodore Lin (not Liu), who afterward ran the Chen Yuen aground, was nominally in command of that ship at the Yalu. Commander McGiffin was her executive officer, but actually fought the ship.

The report that the Chen Yuen's heavy guns were disabled was an error. One of the turrets was jammed for a time, but the main battery kept on firing as long as ammunition lasted. The forward 6″ gun was disabled by an accident to the breech mechanism.

It was also an error to say that the Kuang Ting (Kwang Ping) fled toward the shore. As shown in Commander McGiffin's diagram, she brought up the rear of the retiring column after the battle was over.

The Chih Yuen was sunk in attempting to ram, overwhelmed by gunfire before she reached her target.

The 12″ shell that struck the Matsushima's turret, the very last one in the Chen Yuen's lockers, exploded a pile of ammunition and disabled her 32-cm. gun, besides killing a large number of men. Admiral Ito, however, did not shift his flag until after the battle.

The latter part of the action divided itself into two separate engagements, the two Chinese battleships on the one hand encircled by the five ships of the Japanese main division, while the flying squadron held in check, pursued, or attacked the scattered ships that had formed the wings of the Chinese battle order.

As to the tactical advantage of superior speed much has been written since this battle. One French writer goes so far as to say, "Speed is the principal arm; a squadron which has not an incontestable superiority should decline to fight,"—omitting to explain how the slower squadron can avoid action.† Even an English writer—the anonymous critic in Brassey's *Naval Annual*, 1895—says, "Too much importance cannot be given to the speed of ships and of fleets as a whole." The question is closely connected with the broader one of types of ships and general naval policy. The specialization of types,—as the French call it—torpedo-boats and coast defense ships,—and the sacrifice of offensive power to speed are parts of a theory which is the modern offspring of the discredited and abandoned gunboat policy of the United States, with its corollary of

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* *Marine Rundschau*, February 1895.

† M. d'Arthaud in *La Marine française*, quoted in the *Army and Navy Gazette*, Jan. 5, 1895. See also *La Marine française*, July 25, and Sept. 10, 1895, etc.

dependence upon privateers and commerce-destroyers. Without entering into this discussion let it suffice here to repeat the judgment of Captain Mahan: "Inferiority carried beyond a certain degree becomes impotence; nor will all the commerce-destroyers fancy can picture restore the balance to the nation hopelessly weaker in ships of the line-of-battle." Couple with this the opinion expressed in his review of Commander McGiffin's article, "that a given amount of tonnage in one or in a few big ships possesses a decided advantage over the same, or even a greater amount, divided among several.

Something, however, must be said as to the advantage actually derived from superior speed in the battle of the Yalu. Admiral Ito was enabled by it to keep at a distance; and did so to avoid the Chinese rams, since at long range he could profit more by his superiority in rapid gun-fire than he could have profited at close range by his superior speed in a ramming encounter with an equal number of more heavily armored ships. The Chinese, on the other hand, tried to close, if with any intelligent purpose, not as Herr von Hanneken says to get the full advantage of their heavy guns,—which, other things being equal, would have been more decisive at long range where the enemy's lighter ordnance would have been less effective,—but to ram. This the Japanese superiority in speed, but still more their uniform, close, combined, accurate manœuvring undoubtedly prevented. It is obvious that the manœuvre undertaken by the Japanese van could not have been accomplished without vastly superior speed. But it is equally certain that the tactical advantage gained by it could have been frustrated by the Chinese fleet, notwithstanding its inferior speed, had it possessed any manœuvring capacity whatever. And mark, that in this action the difference was enormous,—at least sixty per cent. (10 to 6 knots) in the main division, and more than one hundred per cent. (14 to 6 knots) in the van—a superiority wholly unlikely ever to exist between two tolerably evenly matched fleets of homogeneous battleships. To say that a fleet superior in ordnance and superior in manœuvring capacity gained great advantage over a disorganized and undisciplined enemy by its immensely superior speed does not prove that superior speed will compensate in fighting—not in running away—for inferiority in armament and drill. Only when other things are equal can the tactical value of speed as such be deduced from the equation. Speed is *not* a weapon, whatever enthusiasts may claim, but only a means of making the best use of all the ship's—or fleet's—weapons. It is like saying that because agility is a good thing for a prize-fighter, and lightness promotes agility, the lighter he is the better. Beyond a certain point lightness weakens the force of his weapons, and so the heavy-weight, slow though he be, can beat the light-weight in the end. A battleship is a compromise of weights. Remember the cost in weight of extreme speed, and the sacrifice of offensive power necessary to attain it. In the light of this experience it may even be questioned if some of the weight given to speed might not more wisely be taken by larger ammunition supply.

A word more about the tactics of the battle. Admiral Ito's official report distinctly states that his column steered first for the centre of the enemy's line. Herr von Hanneken reports that as soon as the enemy was sighted the Chinese fleet weighed and stood directly toward them.* Therefore the fleets approached on opposite courses. This is confirmed by the fact that the battle was opened by a shot from the Ting Yuen aimed at the Yoshino. Then, after the Japanese van had turned gradually to port and a little before it had begun to circle around the Chinese right, the Chinese fleet changed course two points to starboard, trying to keep bows on, which resulted in an irregular wheel, and huddled together the ships on the right flank, which it will be remembered were behind their stations. At the same time the two ships on the left flank, *which had not been in action at all*, took to flight. This accounts for Commander McGiffin, who viewed the action from the Chen Yuen, and does not mention the change of direction of the Chinese line, saying, "as the Japanese fleet approached it steamed along our front from left to right." Commander McGiffin's plan is evidently not drawn to scale, and is misleading as to the distance between the fleets and the direction of the Japanese approach. If the Japanese column had come originally from so far to the eastward, and steamed so close along the front of the Chinese line, it never could have passed its right flank. The photographs taken from the Saikyo Maru, as Lieutenant White points out, show the Chinese fleet at a great distance, approaching bows on. The one reproduced in the *Century*, taken 36 minutes after the Ting Yuen opened fire,† apparently just as the main squadron was coming into action, shows the Chinese fleet still at very long range. A shell has just struck short (on the other side in the picture) of the Chiyoda, the ship next astern of the Matsushima. This seems to furnish the explanation desired by Captain Mahan, of the "manœuvre of steaming in column across the front of the Chinese line, merely to concentrate fire in the end on the right flank, when the left flank could, apparently, equally well have been attacked without the previous punishment." As the fleets approached, their lines of bearing were perpendicular to each other. The Japanese van, opposite the Chinese centre, had to choose which flank to double, and rightly chose the weaker, the Chinese battleships being somewhat nearer the left. The distance of both, and the change of course necessary, to left or right, would be equal in the two cases. The Japanese van passed diagonally along the front of one wing only of the Chinese line, at very long range, and did not open fire until it was about to turn to starboard around the flank, when the distance was still more than 3000 yards. In doing this, it ran no considerable risk. The Japanese main squadron, separated by

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* See also *Marine Rundschau* for February and Mr. Clowes' article in Brassey.

† Commander McGiffin gives the time of the first shot as 20 minutes past 12, not 10 minutes before 1.

some distance from the van, was compelled by the change of direction of the Chinese line to pass more nearly parallel along the front of most of what was left of the enemy's fleet,—for by this time two of the three ships in the left wing had vanished,—but still at long range. When the Hiyei, far astern, came opposite the Chinese battleships, the main squadron *had already passed the right flank.* The danger of presenting the broadside to the oncoming prow of the enemy is only the danger of being rammed. Out of range of the ram, so to speak, there is none. It is apt to be forgotten that in these days of high power and flat trajectory an unarmored ship at least is safer, both with respect to the chance of being hit and to the damage done by hits, broadside on than bows on. Now, even more than a hundred years ago, the worst position an unarmored ship can be in, at ranges where gun-fire alone is to be considered, is where she is liable to be raked. Had the Japanese column attacked the left flank instead of the right, it would have run much greater risk; for the Chinese line would then have changed course, or wheeled, to port, and the whole Japanese fleet would have come into closer range with the battleships. Moreover, the two runaways would doubtless have made even greater haste in their flight, and left the flagship and her mate to bear the brunt of the attack only one ship removed from that flank of the line. As it was, both divisions of the Japanese fleet came first into *close* action, not with the centre, but with the right and weaker flank ot the Chinese line. The range at which the flank was turned was 3000 metres at the beginning of the turn and 1600 at the end. The Japanese opened fire at the first-named distance. If this be greater than naval professional opinion would generally approve, it may be replied that the fire of the Japanese fleet in passing once at that range destroyed two ships outright.

Admiral Ito, in the speech already quoted, gives an interesting account of the previous practice of the fleet, which, as it has not been reprinted in this country, is worth repeating here. Speaking of the time just before the outbreak of hostilities, he says:

"At the same time I felt the weight of my duty was largely added to. I thought it very important at this moment to increase the skill of the squadron in active manœuvres. So we daily practised target firing on the open sea. According to the regulations of the navy only a certain number of shots can be fired from each gun at one drill. I thought the regulation allowance was insufficient for the emergencies of the case, so I applied to the Minister of the Navy for permission to use up the ammunition allowed for practise purposes during the coming year (1895). This was refused and we had therefore to practise for the rest of the time with blank charges. [Possibly this means sub-calibre.] I then equipped the steam launches of the various men-of-war in such a way as to ensure them against severe damage in case of collision, and then divided them into two parties—imaginary squadrons—and appointed the two senior officers of the squadron as the commander of each party respectively, and with them we practised sham fighting. This form of drill is very apt to become half a pleasure, and as a matter of fact in a very short time every boat in the sham squadrons began to evince an inclination to try the ram, as they were all well protected against damage in case of collision. Seeing this, I called a meeting of the commanders of all the boats and cautioned them against any such child's play, pointing out to them that all the vessels we were commanding were not ironclads and were therefore unsuited for ramming. We then set about training so as to avoid any mistakes of actual collision. I ordered all to drill as if they were engaged in actual combat. After this, the tone of their tactics became greatly improved, and all began to manœuvre carefully with a view to avoiding running into each other. This drill was continued until July 23rd, when we received an order to proceed to Chemulpo and moved accordingly."

Both Commander McGiffin and Herr von Hanneken ascribe as one of the chief causes of the Chinese defeat their deficiency in ammunition supply, resulting from the persistent refusal of the authorities at the Tientsin arsenal to furnish shell, of which they had plenty in store, instead of solid shot. Commander McGiffin openly charges treachery as well as official corruption. This undoubtedly was the chief material cause, but it neglects the personal equation. It is rather unfair in Commander McGiffin to claim that the Japanese had twelve ships against the Chinese eight. If he leaves out the two that ran away and the two disabled at the first blow by the superior tactics of their enemies, and omits to count the Chinese torpedo-boats, he ought also to count out the Hiyei, Akagi, and Saikyo, which were disabled early in the action after bearing an honorable part in it, and the last of which was not a man-of-war at all.

It is a pleasure to read Commander McGiffin's high praise of the bravery and discipline of his well-drilled crew and the Chinese sailors in general. Pity is it the same cannot be said of the captains. He thus describes the behavior of Commodore Lin: *

"Commodore Lin was our captain, but he was not to be seen at Yalu. Clearing for action was more than he could stomach even—the fright of anticipation nearly killed him. . . . I kept on hearing a curious noise going on below me in the conning tower every time there was a lull in the firing, and going down there after a while to fight the ship, I came an awful header over Commodore Lin, lying flat on his stomach, cursing and groveling, and praying to Buddha for all he was worth. He belonged to the Mandarin class, and they are all an effete race of arrant cowards."

Some brave officers there doubtless were, but when three out of twelve captains show the white feather what can the physical bravery of crews avail? Someone—I think it was Napoleon—has said, "an army of donkeys led by a lion is better than an army of lions led by a donkey." All

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* In an article in the *Per Mare* quoted by the *Army and Navy Gazette*, August 10, 1895.

praise is due to the foreigners in the Chinese fleet, who, working unsupported against great odds, gave their best service to an ungrateful nation and alone deserve the credit for whatever discipline existed.

Herr von Hanneken thus describes the tactical preparation in the Chinese fleet:*

"On first going on board I endeavored to become acquainted with the conditions under which the squadron was to be manœuvred, and I remarked among other defects that the new code of secret signals was not satisfactory and that it did not respond to all the numerous exigencies of command for a fleet of twelve ships. I saw also that the ships had very different speeds and turning circles, and that in consequence it was difficult for them to execute correctly changes of formation and to keep their places exactly during evolutions. This inconvenience was aggravated by the difficulty of the signals, or the lack of attention that had been paid to understanding them ; but as it was necessary always to be ready to go to sea, I resolved not to change them, fearing to embarass yet more the crews who might not have time to familiarize themselves with my new code.

"These reasons decided me not to regard the twelve ships of the squadron as forming a single group, but to consider them as single ships, able to unite in ordinary times under the command of an admiral, but before the enemy during battle to act individually at their own risk and peril. The commanders of vessels received in consequence instructions based upon the following principles:

"1. In action sister-ships, or each pair of ships belonging to a subdivision, shall remain together if possible and mutually support each other in attack and defense.

"2. The fundamental tactics will be always to keep bows on to the enemy.

"3. All the ships shall follow as far as possible the motions of the Admiral."

Was ever defeat more plainly foreordained? The battle was fought by the Chinese literally every ship for herself. The only tactical theory was to keep bows on at all hazards without reference to the movements of the enemy. The only instance of combined movement was the action of the Chen Yuen, which kept her station and distance from the flagship throughout. Commander McGiffin's skill in directing the movements and fire of his ship so as to cover and support the Ting Yuen when in straits won the praise of his enemies and undoubtedly, as he says, "prevented the fleet from suffering annihilation instead of its actual heavy loss."

The manner of Admiral Ito's attack has been likened by Captain Mahan to Rodney's action off the Saints in 1782, and by Captain Taylor to Phormio's victory at Patras four centuries before Christ: a striking instance

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*Report to Li-Hung-Chang. See also the *Marine Rundschau*, February 1895, and Mr. Clowes" article in Brassey.

of the permanence of tactical principles in spite of change of weapons. If Admiral Ito's tactics were not perfect, if he used his relatively great speed to undertake manœuvres that would have been impossible against an equally fast fleet, or, as Lieutenant Commander Wainwright suggests, that would have cost him dear against a skilfuller foe, no one will quarrel with him, for rashness even, against such tactical lubbers as the Chinese.

Both Commander McGiffin and Herr von Hanneken state that the battle ended by the withdrawal of the Japanese fleet, the latter adding that the Chinese followed them for more than an hour. The Japanese reports state that the Chinese were the first to withdraw. It is unnecessary to reconcile these statements, which are not more different than the testimonies of two witnesses to the same event often are, since the responsibility for discontinuing the action unquestionably rests with Admiral Ito, who had it in his power to continue, while the Chinese had not. He and Commander McGiffin agree that the two fleets stood on parallel courses until dark. Admiral Ito's stated reason, with all respect to Mr. Wadagaki, still seems trivial. He ought not to have "made a picture to himself" of the possible harm from the Chinese torpedo-boats. They were probably worse scared than he. But,—and herein is his justification—for the reason that Mr. Wadagaki himself gives, that "the victory for all practical purposes was already gained,"—the same broad ground that determined the action of Sir John Jervis in a similar case—" he was warranted by the circumstances of that time" in his decision. And he has been amply justified by the result. After this battle the Japanese command of the sea was unchallenged. As Lieutenant White says, "the Chinese fleet was so badly beaten that its battleships only went to sea once afterwards, and then to escape from one port to take refuge in another." As Commander McGiffin says, "before the battles at the Yalu and Ping Yang the Chinese equaled the Japanese in their eagerness to fight; but as the result of these battles gave increased courage to the one, in like measure it disheartened the other."

I cannot agree with Captain Mahan in describing the victory inconclusive. Even its immediate tactical results, considered simply as a naval engagement, were by no means limited to the insignificant Chinese vessels sunk. The battleships were virtually conquered. Commander McGiffin says: " Had they stayed with us a quarter of an hour more, our guns would have been silent and the ships defenseless." It may almost be said that the surrender was merely postponed from the Yalu to Wei-Hai-Wei; for although the two armorclads fought bravely and stubbornly there, surrounded and attacked by land and sea, they were literally caught in a trap whence there was no escape. From the day of the Yalu they had abandoned their strategic mobility and no longer exercised even the deterrent influence of a "fleet in being." Instead of saying, "the subsequent demoralization of the Chinese left to their enemies the control of the sea, which was decisive of the war, but which the Yalu fight alone would not have conferred," it seems to me truer to say that the victory of the Yalu was the immediate cause of the demoralization of the Chinese navy, which, like the Spanish after Valentine's day, "could no longer be counted a factor in the political situation."

On the strategic question raised in the discussion I beg to differ with Lieutenant Commander Wainwright. The governing conditions undoubtedly are, as he states them: "Where a whole coast or a great commerce must be protected from a fleet, it is sound strategy to blockade closely that fleet, for there being many weak points, it is impracticable to guard all; but where there is one weak point it can be protected best by holding the force at or near the point." It may be added that when the points of departure of the fleet to be watched are few—or one—the reason is all the stronger for blockading it there. Now in this case it seems to me that Japan in her position in Korea had to fear, not for the safety of her army in Ping Yang only or chiefly, but the landing of Chinese troops anywhere on the peninsula. Like England, she had many points to guard. In Korea, with respect to descents of force from China, her general attitude was for the time defensive. Admiral Ito must—or may—have known of the orders of the Tsung-Li Yamen forbidding Admiral Ting to cruise to the eastward of the line from the Shantung promontory to the month of the Yalu river. So actually he had little to fear for the army in the Ping Yang inlet; and the Chinese transports in fact landed not there but in the Yalu river. If it be replied that this is reasoning from knowledge after the event, then it seems to me that against the moral weakness of the Chinese government Japan was justified in assuming the most aggressive offensive, notwithstanding her supposed inferiority in physical force, which actually, considering the quality of her fleet, was more apparent than real. Control of the sea was all-essential to the safety of the Japanese communications; no time ought to have been lost to win it. Had the Chinese fleet been defeated before the landing of troops at Wiju, some subsequent fighting on the march of the Japanese army would have been saved.

It seems to me, also, that the Japanese fleet was strong enough to blockade the Chinese in Port Arthur or Wei-Hai-Wei. Admiral Ito's force was not limited to the eleven ships present at the Yalu. The "Combined Fleet" was divided into the Principal and four Auxiliary squadrons, of which the Principal and first Auxiliary only were engaged in that battle.* The ships composing the second Auxiliary or Western Sea squadron are not named, but the other two contained eleven or twelve cruisers and gunboats. These vessels were not all very fast or very modern, but they would have sufficed for scouts against the slower Chinese fleet, as well as they did as convoys to their own transports. Some of them were in fact "sent daily on scouting expeditions towards Wei-Hai-Wei and elsewhere."

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* See Admiral Ito's speech previously quoted, and the pamphlet by Jukichi Inouye.

But Admiral Ito, even if he were not able to press into service more mail steamers like the Saikyo Maru, might at least have kept in constant touch with the Chinese fleet without weakening his "Main" and "Flying" squadrons. It may even be questioned if he would not have been better off in the battle had he left the Hiyei, Akagi, and Saikyo behind. They won the largest share of glory, but in truth were a hindrance rather than a help to the fleet.

But in stating what I believe would have been sounder strategy, I am far from blaming Admiral Ito. He acted under direct orders from headquarters in convoying the armies. The criticism is made wholly upon military grounds, without taking into account the political conditions, which must always influence the action of a commander-in-chief, and with admittedly incomplete knowledge of the general operations of the war. It must be remembered, too, that before the battle of the Yalu all the world thought China possessed the far superior fleet. The Japanese themselves distrusted their navy, ships and men ; the administration of the department and the professional ability and even the discipline of the service had been the object of violent condemnation in Parliament and in the press ; Parliament had repeatedly refused or only reluctantly granted appropriations for its increase, not on the ground of disagreement with the national naval policy of the Government, but because of the openly charged corruption of the administration and the alleged inefficiency of the service itself.* Admiral Ito's highest honor lies in having demonstrated to the Nation in the crucial proof of war that its fears and its mistrust were groundless.

Happy is it for Japan that in the winter of 1893—in time of peace—when the controversy over the naval appropriations resulted only in repeated upheavals and adjournments of Parliament, the wiser steadfast counsel of the Government prevailed. The lofty patriotism and farsighted policy of the Emperor himself settled the dispute by ordering the contribution of one-tenth of the salaries of all officers of the Government, civil, military and naval, for the term of six years, to the fund for increasing the navy ; and himself headed the list by the gift for the same period of one-tenth of the imperial income, amounting to three hundred thousand yen. While we wonder at the authority exercised by a Throne, still hedged around with a majesty half divine whose very reality is strange to our republican eyes, the prophetic words with which the Emperor closed his famous rescript deserve to be had in everlasting remembrance: "A single day's neglect may involve a century's regret."

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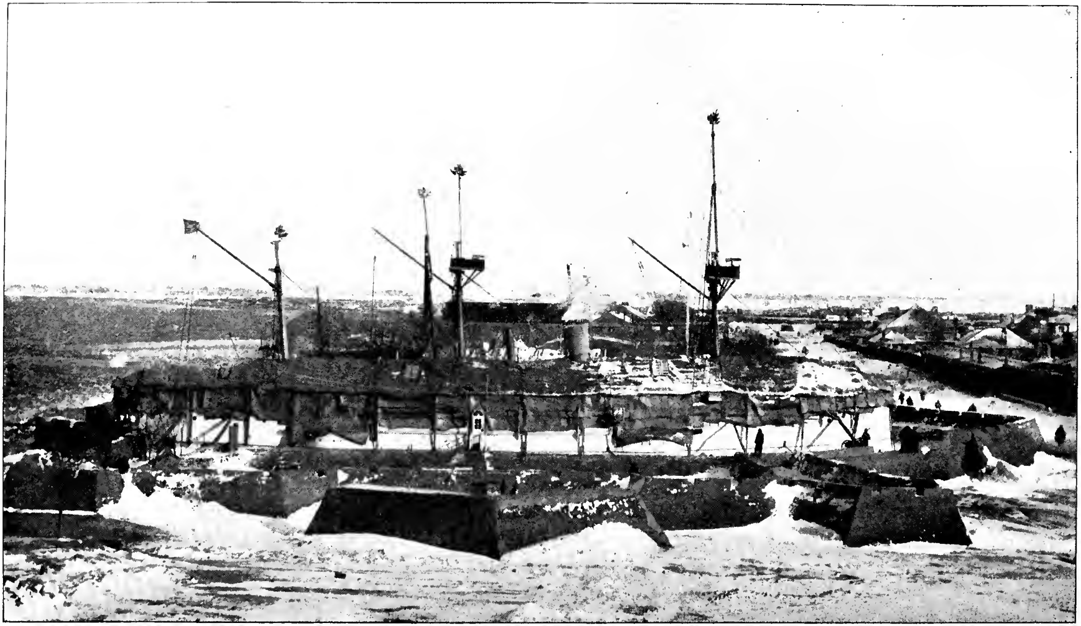
* See the preface to Jukichi Inouye's pamphlet, and George N. Curzon's "Problems of the Far East," pp. 28-46, etc.



U. S. S. PETREL, CHRISTMAS, 1894.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE PETREL'S INSTALLATION IN MANTCHURIA DURING THE WAR BETWEEN CHINA AND JAPAN.

By LIEUTENANT N. SARGENT, U. S. Navy.

The phenomenon of a modern steel war vessel in commission on a foreign station, and containing a full complement of officers and men, equipment, munitions and stores, remaining for nearly half a year high and dry on shore in a savage country alternately overrun by two Oriental belligerents, and cut off from all connections with the outside world, would under any circumstances be a novel and surprising one; and when, moreover, such an extraordinary situation is the outcome of the natural demands of the service and is due to no fault nor error of judgment, but to a preconceived and carefully worked out plan, it would appear to form a sufficiently unique experience to merit description, and as one of the many anomalous contingencies to which the naval officer is liable, and in which his professional knowledge and ingenuity are drawn upon in entirely new and unexpected directions, a recapitulation of some of its features may not be devoid of interest to members of the Institute.

In October, 1894, the U. S. S. Petrel was in Nagasaki, Japan, undergoing repairs to engines and boilers consequent upon several months' continuous and arduous cruising in Bering Sea, when orders were received to proceed to, and presumably winter at Newchwang, the most northern port of China, for protection of its foreign residents; such protection, always more or less necessary in Chinese treaty ports, being at that time especially so on account of an ultra animosity to foreigners, consequent upon the existing hostilities between China and Japan.

These orders were received late in October, and upon such inquiries as could be made concerning the *terra incognita* of Newchwang, a port rarely visited by any of our vessels, several items of information were obtained, which may be recapitulated as pertinent to a comprehensive conception of our subject.

Item A.—That Newchwang was not Newchwang at all, but was called by the Chinese, Yingtze, and sometimes Yenkow, the real city of that euphonious appellation being situated some twenty miles distant, and inland, Yingtze being its port and having appropriated its name.

Item B.—That this so-called Newchwang was a city of Mantchuria, with a population of 70,000 native inhabitants, and a small foreign colony then augmented by some refugee missionaries ; that it was to be found at the head of the Gulf of Petchili and fifteen miles above the mouth of the Liáo river, whose navigation was closed from November until April, and that before and after the solid freezing of the river, great floes of ice some thirty inches in thickness, charged up and down its course with every change of tide, and with such force as to render it an impossibility for any vessel to remain at anchor off the town.

Item C.—That a provisional dock could be cut in the soft mud of the river's bank, and that in such a dock the ship might winter and be fully protected from the ice ; also, that two precedents for this alternative existed, neither of them very reassuring, but evidencing the possibility of such a plan. The first had been the case of a small British gunboat, H. M. S. Grasshopper, which had been ordered to Newchwang in 1870, but had unfortunately broken her back in entering such a dock, so that she was useless for any further work, and in the spring was sold as old material ; the second, that of the U. S. S. Palos, which some ten years later had wintered at Newchwang, and had been docked and undocked successfully.

The latter case was hardly more encouraging than the former, for the contrast between the size of the Petrel with her 890 tons displacement, length of 176* feet and beam of 31 feet, and that of

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* Compare this with the length of the old sailing frigates and sloops of war: Constitution, 176 feet ; Constellation, 176 feet ; Portsmouth, 153 feet ; Saratoga, 147 feet.

the Palos, 420 tons, 137 feet length and 26 feet beam, made it very questionable if the experience of the Palos could be taken as a criterion, and if the docking could be accomplished without serious risk to so much larger a vessel.

Item D.—That H. M. S. Firebrand, an antiquated British gunboat of 455 tons, and with a crew of only 45 men, was to keep the Petrel company in her Mantchurian port for the winter.

Item E.—That an inspirating and what was later found to be a quite accurate description of the Petrel's prospective station, could be obtained from the Sailing Directions,* which, on this occasion, seemed to depart from their usual imperturbable enumeration of headlands or dispassionate description of rocks and shoals, and to regard the case as one demanding a certain degree of melancholy eloquence—as may be judged from the following excerpt:

"It is a dreary place. The muddy river winds through a plain of mud without a single natural elevation to break the dismal monotony of the scene, and indeed except for a few weeks during summer, the region in which the port is situated is little more cheerful than an Arctic swamp." To which may be added the pithy dictum of an English traveler, who aptly terms Yingtze "a putrescent cesspool." †

Such scanty information was all that was obtainable, and as there were but a few weeks remaining in which to accomplish the object of our mission there was no time for delay.

The November spring tides happened to come in the second week of the month, and failing to take advantage of these, it was questionable if the dock could be entered at all before navigation closed. An order was consequently telegraphed, and the dock was fairly under way when the Petrel arrived on November 7th.

The first part of the excavation was comparatively easy, the ground being of soft mud, with no rocky formation, but the latter part was hindered by the opening out of springs and quick sands, and by the discovery of certain strata of sand through which the water of the river percolated.

It was specified that the dock should be 220 feet long by 40 feet wide, and that there should be a depth of at least 13 feet 6 inches

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* Chinese Sea Directory, Vol. III, p. 655.

† Travels in Mantchu, Tartary, by George Fleming, Esq.

upon the sill, the vessel, after having been lightened and trimmed to an even keel, drawing 12 feet 2 inches both forward and aft; but great difficulty was experienced in getting even 13 feet on the sill owing to an abnormally high tide which had prematurely broken in the as yet uncut gate, and had flooded the dock.

The weather was getting colder each day, the temperature falling below the freezing point at night, and as the Chinese coolies could work upon the sill only at the lowest point of the tide, had no dredger of any kind, but were obliged to dig waist deep in the freezing water, it was doubtful for some time if the requisite depth could be obtained. However, by persistent effort all difficulties were overcome, and on November 12th, a first attempt was made to enter.

The first and even the second and third attempts were unsuccessful, and it was only by a dogged perseverance and by forcing the ship through the mud of the sill with less than 12 feet of water upon it, that she was finally successfully docked. The operation was a hazardous and an extremely difficult one, owing to the following reasons:

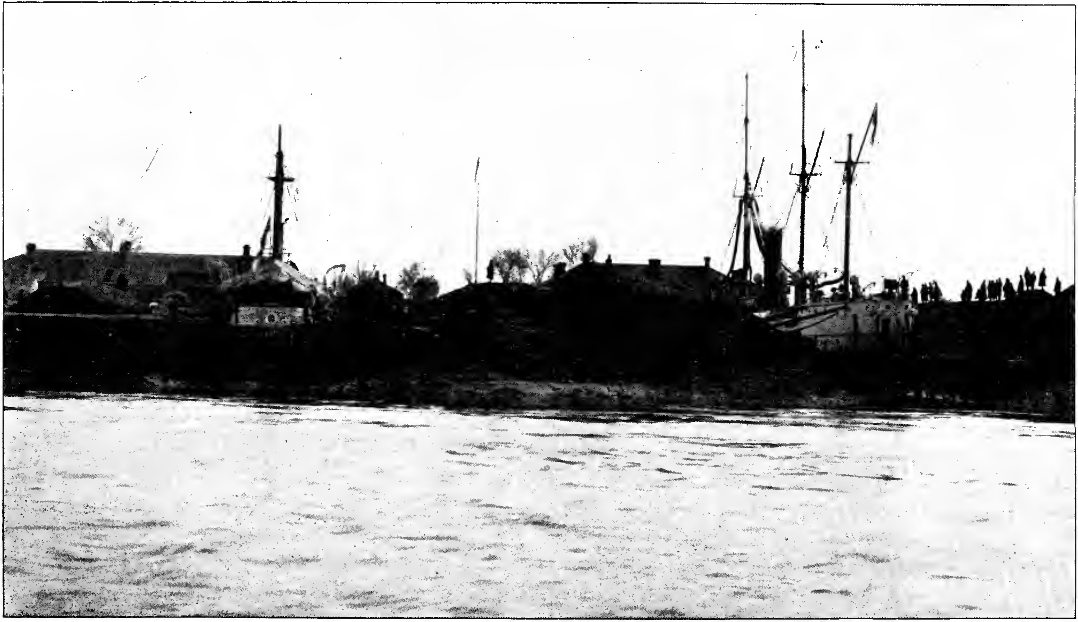
1. The tides in the Liáo, as in many rivers, run with great rapidity, especially at springs.

2. The ebb in shore begins a full hour before the flood ceases running in the center of the stream, thus forming counter currents each of great force, and giving no period of absolute slack water.

3. The best moment to enter the dock was naturally the one when the tide gauge on the sill showed the highest rise of water.

From this it may be understood that when approaching the bank great allowance had to be made for the rapid flood current in the stream, and that on nearing the entrance an almost equally strong ebb was encountered, both currents affecting the vessel at the same time, thus forcing her from her normal position to the bank and bringing her nearly parallel to the shore and obliquely on to the mouth of the dock.

However, by grounding on the corner of the dock, working the engines and helm, backing to drive the water in, and then going ahead full speed to take advantage of the extra depth thus obtained; by heaving with the steam capstan on wire and manilla hawsers bent to anchors which had been buried deep in the ground at the head and on the sides of the dock, and by using others attached



U. S. S. PETREL, TWO DAYS AFTER ENTERING MUD-DOCK.

as guys to the quarters of the ship and manned by hundreds of jabbering coolies on shore, the vessel was at last gotten in. For a week every one had worked day and night, all were fagged out, but the ship was uninjured and the work had been successful.

But what a situation and how hopeless the outlook for the first few days! The natty little vessel whose trim appearance had been the pride of all on board, lying in a hole of slime and water, with decks and sides begrimed with mud, and encompassed with mounds of slippery earth, surmounted by curious groups of Chinese coolies, soldiers and vagabonds of every description, only eager to pilfer or to turn an honest penny by selling liquor to the men; the latrines for officers and men but half completed, the dreary outlook, the town in a state of panic and outrages from Chinese looters expected at any moment and most likely to occur simultaneously with an attack by the Japanese—altogether there have been pleasanter prospects.

But chaos was soon resolved into order, the dock was pumped out and closed, a fortified enclosure sufficient for protection of all the foreign residents was built, the ship stripped and covered in, stoves put up, precautionary measures for fire arranged, water for distilling, lighting and heating provided, military tops constructed, etc, etc.; so that before the last steamer had left and the place had been temporarily cut off from the outside world, the comfort of the crew had been assured and "Fort Petrel" was ready for any emergency.

A short résumé of the work done to accomplish this result will be given under its different appropriate headings.

The Dock.—This was distant some twenty feet from the mean high water mark on the river bank and was 220 feet long by 40 feet wide. As before stated, it was cut into the mud of the bank, this soft earth making an excellent cradle for the ship when the water had been gotten rid of.* The ship was centered by springs and warps, and as the water subsided was plumbed by hawsers to the mast-heads, which held her in a vertical position until all the side shores could be placed. The gate of the dock was then filled in with earth held in place for greater security against leakage and also for protection against the overriding foot ice of the

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* On account of the mud and slime in the bottom of the dock it was impossible to place any keel blocks.

shore, by large squares of indigenous rush matting and a crib work of spiles secured by a frapping of old wire hawsers. The dock was then thoroughly roofed over by a bamboo frame work covered in turn with rushes and a layer of mud mortar, thus forming a covering for both warmth and for protection to the metal of the ship's body.

Pits were dug for latrines for officers and men, sufficiently distant from the dock to prevent any transudation into it (*vide* plan), and over these adobe houses were built, giving space for latrines, urinals, washroom for the men with a species of boiler for heating water, and a blacksmith shop. The arrangements of these buildings added greatly to the comfort of the ship's company during the long months of the semi-arctic winter.

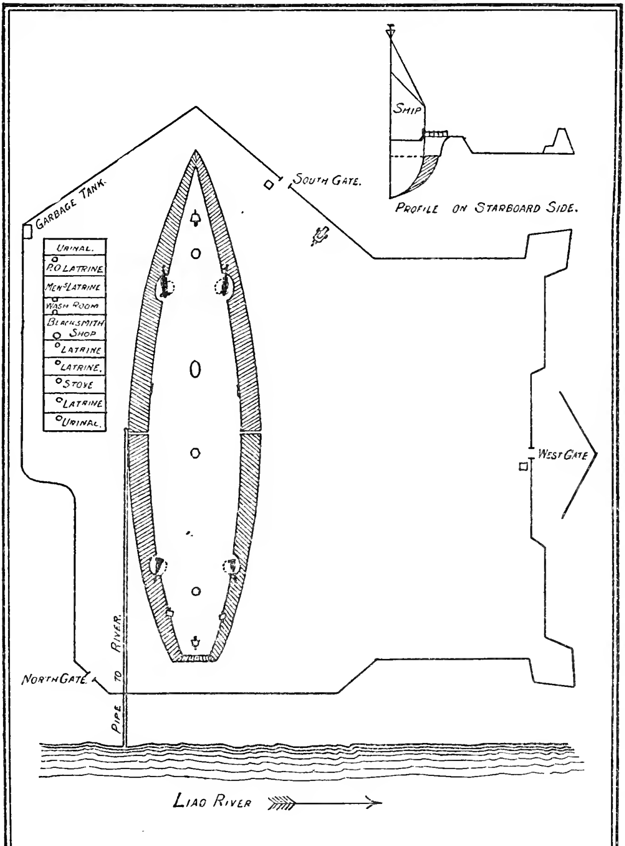
The Fortified Enclosure.—This, under the circumstances, was an absolute necessity not only for the privacy and autonomy of the ship, but also as a place of refuge for the foreign population in case of hostilities or of an uprising on the part of natives.

The excavated earth from the dock formed a ready means of constructing such an enclosure and its lines were at once laid out, special attention being paid to the approaches from which danger was apprehended, and care being taken to preserve a field of fire for the main battery of the ship in case as a last resort this should be needed. The usual profile of fortifications was somewhat modified or inverted to suit the exigencies of the case, the ditch being found next the vessel in the dock itself, and a rampart or species of glacis being left at the edge of the dock for protection against rifle or heavier projectiles.

The parapet of the fortification was eight feet in height, some twelve feet thick at base, and was of the ordinary shape; except that to economize space and so give a greater area for a drill and recreation ground, the banquette slope was more acute than usual and was fitted at intervals with steps for mounting to the banquette tread, while the top of the parapet was crenelated for rifle fire; an emplacement was also provided for a Gatling mounted on its field carriage.

Three openings were left, which were filled in with thick wooden gates, amply secured with heavy iron bolts improvised from broken grate bars and fashioned by the ship's blacksmith.

The main entrance was also defended by an outside curtain or redan. Across the filled-in gate of the dock, a wall eight



OUTLINE OF FORT PETREL.

Scale.
$\frac{1}{6}$ inch = 10 feet

feet high of unburnt brick connected the two ends of the earth works.

The whole enclosure when completed gave a continuous line of earthworks about the ship with ample space for the latrines, etc., on the port side, and on the starboard, a parade ground or *terre-plein* 130 feet long by 90 wide. The accompanying outline will show the general disposition of ship and fortification, while the sectional view from the starboard side, gives the profile of ditch, glacis, drill ground and parapet.

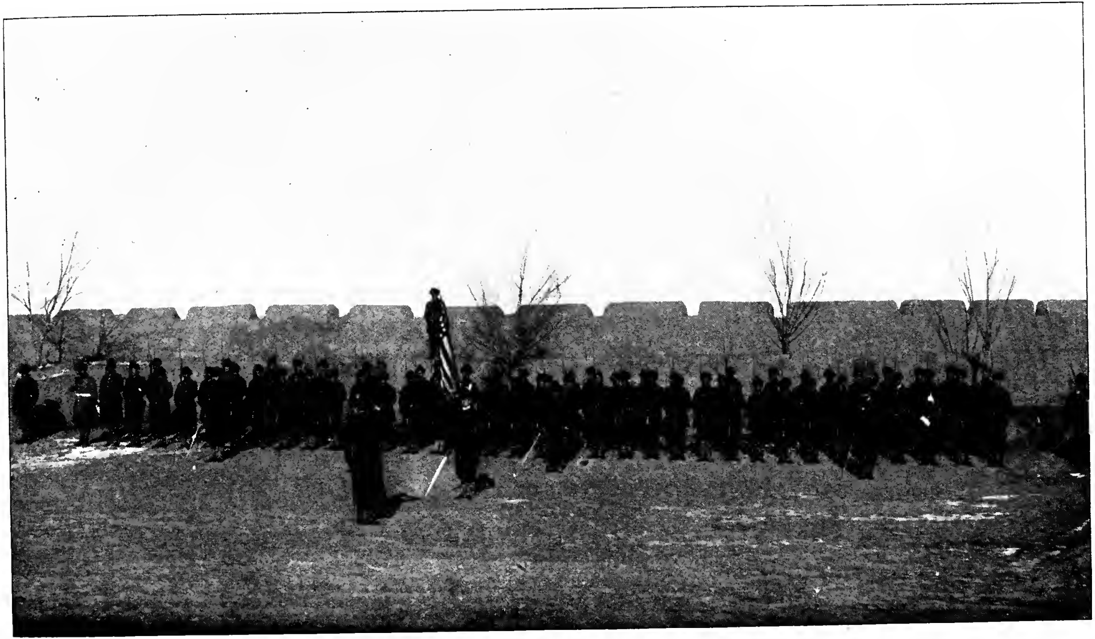
The Ship.—As soon as fully shored and secured, the ship, which is barkentine rigged, was stripped to a girtline on the main and mizzen, but the fore top-mast was left in place for observation purposes, a wise precaution as was proved later, when it became necessary to have a look-out continually aloft to report upon the movements of the Chinese and Japanese troops outside the city walls.

Yards, masts, rigging and stores were stowed in a godown belonging to the American Vice-Consul. The boats were buried on shore in sand, to preserve them from the effects of the extreme dryness of the winter atmosphere and the ship was housed in with a framework of bamboos and poles, fastened like Solomon's temple without sound of hammer, axe or any tool of iron, it being secured together by lashings of coir rope and covered with heavy rush mats, each some twenty feet square, over which in turn a layer of mud was plastered as a protection against fire. This roofing was about twenty feet high amidships and twelve feet above the deck at the sides, the part from edge of scantling to top of ship's rail being hung with smaller and more closely woven mats, fitted with brailing lines in the wake of the guns, so as to roll up to the ridge poles of the scantling when the guns were manned.

A similar arrangement was made at the search light position.

Brows for either gangway and doors, closing the entrances in order to keep out the cold air, were also constructed.

For greater command of the approaches to the ship it was deemed necessary to have some machine guns aloft, and as the vessel was not furnished with military tops, these were made of heavy timbers bolted to the trestle-trees and shored to chocks butting on the futtock bands. An ingenious crinoline mount was



INTERIOR OF FORTIFIED ENCLOSURE.

improvised by the Chief Engineer from some bar iron with an old valve as pivot socket, and a 37-mm. Hotchkiss revolving cannon was mounted in the fore, and a 45-caliber Gatling in the main top.

The other rapid-fire and machine guns could also be efficiently used from their ordinary positions on the forecastle, poop and rail, while, as before mentioned, in case of urgent necessity the main battery could be brought into play. More attention was paid to the starboard than to the port-side, because of the position of the Firebrand on the port beam, and also because the Chinese quarter of the town was situated on the starboard side of the ship.

Strategic Dispositions.—The distances of different salient points of the foreign concession were measured for lines of fire, day and night danger signals for warning the foreign residents determined, and a division of labor for rescue parties from the Petrel and Firebrand in case of emergency agreed upon, the Petrel as the larger vessel taking the lion's share of the work.

Domestic Economy.—The questions of distilling water, of lighting and heating the ship, and of protection from fire when all was ice and snow, were most important problems which called for an early solution.

Before leaving Nagasaki, 250 tons of coal were ordered from Shanghai, and 180 feet of 2½-inch iron piping were obtained and shipped to Newchwang.

With this piping a connection was made with the river, though on account of the low temperature during the winter, the pipes could not be used for ordinary purposes, but were reserved for case of fire.

Water for distilling was carried each day by coolies hired for the purpose, this being an absolute necessity on account of the pernicious character of the local water, so that for the whole term of the vessel's stay in dock, there was no lack of good distilled water. The leakage from the river into the dock, which could not be wholly prevented, was also kept down and utilized for the boilers, and was useful in making steam for electric lighting and for the steam heaters. The latter with the extreme degree of cold experienced, were insufficient for heating the ship, so that such stoves as could be purchased were mounted on the spar deck, in the cabin and in the latrines.

With the inflammable nature of the roof and dock covering, special precautions against danger from fire were necessary, and to this end all the after pump system of the ship was kept connected up, the pipes above mentioned were laid to the river, a special fire-bill made out, grapnels were fitted with long lines for tearing down the scantling and mats, life lines were conveniently placed for men stationed to cut open the river ice (which could not be kept constantly clear on account of the continual changing of the foot ice, with the rise and fall of the tides), and extra squads of axemen, smotherers, etc., were detailed. Fire hand-grenades were also placed in all parts of the ship in addition to those already in position. Two divisions were detailed as bucketmen, and a large wooden tank eight feet long by five wide was constructed and mounted on the spar deck, kept filled with water, which was prevented from congealing by means of an evaporator coil and steam jet.

Hygiene.—The question of personal cleanliness, always of great importance in such a crowded community as that of a ship's company, was made vitally so by the advent of cold weather and by the consequent disinclination of certain slovenly members of the crew to indulge in more than a very superficial scrubbing. The washroom in the outhouses was heated and hot water was always ready in the morning for the general use of the men, and at night for the different divisions of the ship, who in regular turn were obliged to use it for bathing purposes, the petty officers being required to report that all their men had taken a thorough bath. Clothes and hammocks were scrubbed ashore by native laundrymen and bedding was frequently aired; all living spaces, outhouses, etc., were rigorously inspected each day, the sinks treated with a disinfectant every morning and great supervision exercised over all provisions brought on board.

With the many drills and the daily setting up exercise the men were maintained in most excellent physical condition, and even when on some rare occasions the weather was too severe for drilling, the ship's company was taken out for a brisk run of twenty minutes in the frosty atmosphere, returning with ruddy faces and hoary beards, but in a healthy glow whose effects lasted for hours afterwards.

For the comfort of the men fur caps (of the Elsinore pattern, with large flaps to cover the back of the neck and the ears) and single finger mittens were obtained, while sheep's skin linings to pea-jackets were allowed, sentry boxes provided, etc. In unusually cold or blustering weather the sentries were relieved every hour, and only one case of slight frost-bite occurred. The effect of such attention may be appreciated from mentioning the fact that in a battle between the Japanese and Chinese on February 24th, which took place only ten miles outside the walls of Newchwang, and when the thermometer was ten degrees below zero, fifteen hundred of the former had their feet frost-bitten.

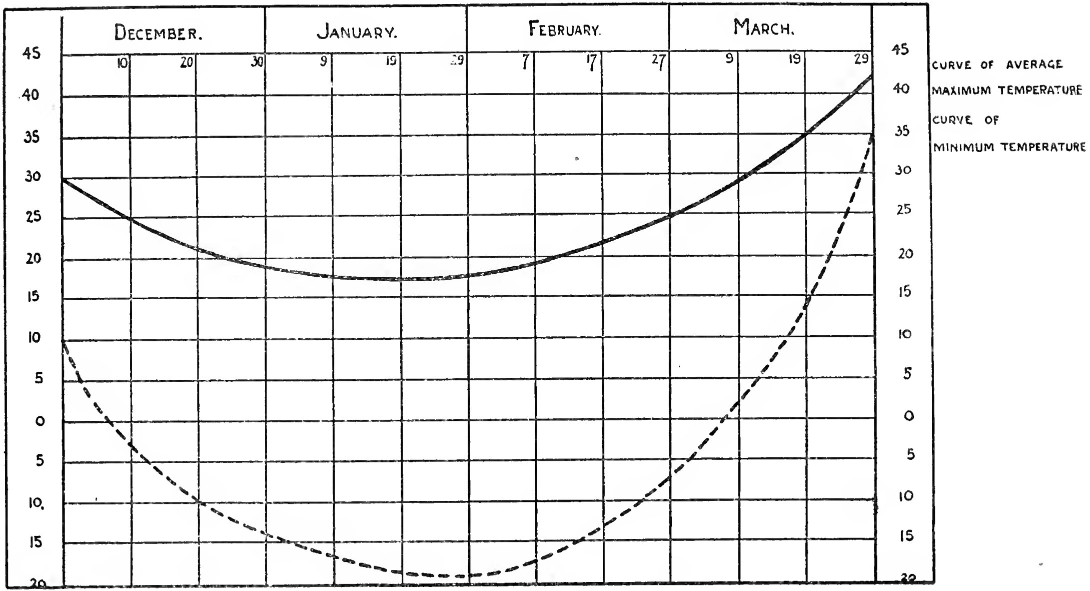
Weather.—Although Newchwang is in the latitude of New York the winters are unusually severe; the temperature is not abnormally low, it rarely falling below minus 20° Fahrenheit, but on account of the high winds or blizzards, which are very prevalent, the cold seems much more intense than it is in reality.

There is comparatively little dampness, but a brilliant, rarefied atmosphere, like that of our Western plains, is the redeeming point of the long winter. Snow falls in November, and at intervals until the middle of March, the ground being continuously covered with it, and not the least of the Petrel's experiences was that of keeping the enclosure clear of this objectionable substance.

Though the cold at times was intense, there were very few days during the whole season when the routine drills could not be carried on. The river was frozen over during the entire winter and served as a passage way for the troops of both belligerents on many different occasions.

The annexed diagram will show the curves of temperature from December 1st to March 31st.

Personnel.—Efficient discipline, constant employment and a fair amount of physical exercise for the people of the ship's company was naturally a subject of earnest consideration. From the moment of entering the dock an organization on a more military basis was a necessity. All men of every department of the ship were apportioned to the battalion; a daily guard detail, with regular morning guard mount at 9 A. M. was formed for outside sentry work, the small marine guard of only ten men being insufficient for this purpose, and being left to their customary duties on board. The rifles were numbered and allotted to the men, each man being responsible for the condition of his piece and



CURVES OF TEMPERATURE.

having it inspected daily at morning quarters, while the policing of the grounds and outhouses was done by extra duty men.

A special routine was made out providing for morning, afternoon and evening drills; and all hands were thoroughly exercised at General and Fire Quarters by day and night, at marching, bayonet exercise, skirmish and street riot drills in good weather, and at other times in revolver practice, aiming, great guns, single sticks, setting up, stations, etc., etc.

At General Quarters all gun divisions were armed as riflemen, and when called away the men of these divisions manned the ramparts while their places at the guns were taken by the powder division.

During the battalion marches all the salient and outlying points for protection were pointed out to the officers and men so that in case of need the rescue duties could be intelligently performed, while simulated attacks on "Fort Petrel"—the men being divided into parties of defense and attack—gave every one an opportunity of judging what surprises might be anticipated and what weak points should be particularly guarded. In addition to these exercises al the standing and running rigging was thoroughly examined and refitted, sails and canvas work put in order, signals and other flags made and repaired, machinery overhauled, blocks, boat gear, etc., looked after and in every way occupation furnished for the men and the ship kept in thorough condition. For the amusement of the ship's company parallel and horizontal bars were erected in the enclosure, quoits provided, a tug of war occasionally indulged in and missionaries allowed on board two evenings in the week for a religious and musical symposium. A daily liberty list for the good conduct men was also made out, they being allowed at certain intervals leave until 9 P. M., except on days when the excited feeling was at its height and when there was a possibility of the battalion being called upon, as indeed happened on several occasions.

The men behaved admirably in all respects save one; despite the Utopian theories of certain optimists, who argue that marines may be dispensed with, it was found that the sentries and even the petty officers of the guard could not in many cases be relied upon to prevent the introduction of liquor, and this one subject was the cause of much annoyance and necessitated the most unceasing vigilance on the part of the officers and the police authorities of the ship.

All those who have passed a few days in dry dock can easily recall the troubles that have invariably arisen, and can therefore comprehend the difficulties attending five months in the same predicament.

Stringent orders were issued to prevent any possible conflict between the men and the natives, and it was greatly to the credit of the former that, although the place was filled with thousands of troops, many of them so called "Hunan Braves" from a province noted for its antipathy to foreigners, no trouble of any kind occurred.

There can be no doubt that the presence and the efficient installation of the "Petrel" resulted in the maintenance of law and order, in place of the riot and outrage which would otherwise have prevailed.

Upon her arrival the city was found to be in a state of panic; the Chinese portion of the town was terrorized by some hordes of Mantchurian desperadoes, who, thrown out of employment by the war, had taken refuge in Newchwang, and had regularly organized themselves for the express purpose of looting the place and of murdering all foreigners ; European women and children were leaving, native merchants were closing their shops and fleeing south by every steamer, and all signs pointed to an anarchial state of affairs accentuated by a savage paroxysm of hatred to foreigners.

The moral effect of the Petrel's guns and fortifications soon however gave a different aspect to the situation.

The Taotai (Governor) who was in a lamentable state of trepidation, was encouraged to enforce his authority, and was not only enabled to preserve comparative order, but was emboldened to exclude objectionable refugees (notably the routed army from Port Arthur, which was refused admittance) and to repress lawlessness by decapitating some dangerous characters who were caught placarding the town with inflammatory proclamations.

Both the Taotai and the foreign consuls and residents on many occasions reiterated their assurances that the fortifications, presence and significant preparations of the Petrel had been of inestimable advantage to property and life.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

PRESSURE OF SMOKELESS POWDER GASES IN THE BORE OF GUNS.

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(Translated from the Russian by Lieut. John B. Bernadou, U. S. N.)

1. At the present day smokeless powder is being brought into general use for firing from cannon as well as from small-arms.

Recent experiment shows that for the varieties of smokeless powders tried by us the charges develop greater initial velocities for a given maximum pressure than are developed by charges of saltpetre-sulphur-charcoal powders producing the same maximum pressure.

In consequence of this property of smokeless powders, greater pressures are developed by them in parts of the bore near the muzzle than are produced in those parts by the black and brown powders. As a result of this, two important questions arise: (1) To what extent may smokeless powders be employed for firing from guns of present day types? (2) What should be the construction of guns in the future, so that the full advantages to be derived from the use of smokeless powders may be realized?

With the view of ascertaining the ballistic properties of smokeless powder, and also for obtaining practical data for the solution of the above questions, a series of experiments was undertaken by Colonel Yakeemovitch and myself, under the direction of the Artillery Committee, to determine the distributions of pressures realized from firing charges of smokeless powder from guns of the following calibres: the light gun (3.42-in. cal.); the 4.2-in. gun; the 6-inch. gun of 190 poods (7600 lbs.) weight; the 9-in. gun; and the 11-inch of 25 and 35 calibres approximately.

2. At present the experiments with the light gun, the 4.2-inch and the 6-inch of 190 poods (7600 lbs.) weight are concluded. Detailed accounts of these firings are given in the appended tables.

For the registration of pressures at various points along the bores of the above mentioned calibres, crusher gauges along the sides of the bore and in the breech block were employed.

In using the crusher gauges preliminary shots were fired for the determination of the corresponding preliminary compressions of the copper disks, which should differ from those corresponding to the pressures that would be received upon the firings by about 100 atmospheres.

In conducting the subsequent series of shots (in fives), to be utilized in determining the mean magnitudes of the pressures at different points along the bore, each disk was thus compressed by a second pressure, approximately 100 atmospheres different from the first; and from the result of measurement of its height its special coefficient was calculated.

3. Not losing sight of the fact that the pressures measured by the method employed in the experiment do not correspond exactly to the true pressures developed, nevertheless we may observe that there exists a definite relation between the pressures developed at various points along the bore and the distances of these points from the base of the bore, for all varieties of smokeless powders experimented with. I have deduced the equation expressing this relation and I have ascertained, by application of the method of least squares, the coefficients for the same, based upon the results of the firings with the light gun and the 4.2-inch. I was unable to utilize the results from the 6-inch in the formation of equations, for, with the varieties of smokeless powder employed, a fall in pressure was only to be noted for the three gauges placed nearest the muzzle; the remaining gauges registering approximately the same pressure; so that the experimental data were not sufficient to permit the determination of the form of the pressure curve. The obstacle arose from the fact that the gauges were grouped together close to one another on that part of the gun

strengthened by hoops, which part was comparatively short; and there were only two gauges placed along the unsupported portion.

Having developed the pressure curve, I calculated the work of expansion of the powder gases in the gun available for propelling the projectile.

As the law of variation of pressure upon the base of the projectile from the beginning of its motion to the point of maximum pressure in the bore of the gun cannot be ascertained from experiment with the aid of side crusher gauges, I estimated the pressures for this part of the motion of the shell approximately, defining the curve of pressures by the aid of ordinates calculated by means of the theoretical formulæ of M. Sarrau, Member of the French Academy of Sciences ("Nouvelles Recherches sur les Effets de la Poudre dans les Armes." 1876).*

In almost all cases examined the calculated work falls somewhat under the muzzle energy of the shell. This discrepancy is explained in part by the fact that the muzzle pressures are less reliable, as with disks of the diameters employed, and for pressures of about 300 atmospheres, the disks frequently do not register the residual pressures; or else, the compression is insignificant, as the load approaches closely to the elastic limit of copper, and the disk only compresses under the action of the elastic force. Moreover, the measured pressures may be assumed as less accurate owing to the very brief action of the pressure in these parts upon the copper disks of the gauges.

The equation for the pressure curve developed by me is such as to afford a very simple way of computing pressures at various points of the bore when the pressure at the breech and the initial velocity are known.

For this purpose, having indicated the pressure by means of my equation, we assign to the maximum pressure its place in the bore of the gun (the maximum pressure approximately equals the breech pressure); from the energy of the shell at the muzzle we determine the coefficients of the equation; and we then calculate the pressure at various points along the bore.

The point of the bore for which the pressure reaches a maximum may be approximately determined from the results of the firings with the light gun, the 4.2-inch and the 6-inch.

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* See Proceedings U. S. Naval Institute, Vol. X, No. 1, 1884, Whole No. 28, for an English translation of Sarrau's Researches on Powder.—ED.

It is not to be expected that the pressures calculated by the proposed method for various points along the bore represent the true pressures; they are only approximate and serve for estimating resistances of guns designed in the future, for various points along their lengths.

Besides deducing the equations of the curve of pressures, I have discussed other points relating to interior ballistics in my work: namely, I have deduced formulæ for determining the rate of motion of the projectile at various points along the bore, the corresponding times elapsing from the origin of motion, and the pressure of the driving edge of the rifling upon the rotating band of the projectile; besides which I indicate a way of determining the angle of parabolic rifling at its origin, so as to diminish as far as possible the pressure upon the rotating band.

In concluding my work I have, by employing the experimental results and formulæ of Sarrau, given in the memoir above referred to, determined the force of the powder f, and the fractions of the charge burned in various sections of the bore; and finally, I have deduced empirical monomial formulæ for determining initial velocities and breech pressures, using smokeless powders. These formulæ differ from those deduced by Sarrau in the signification of certain exponents of terms expressing the weight of projectile, weight of charge and density of loading.

§ I.

EQUATIONS OF PRESSURE.

4. In order to ascertain the pressure of the gases accelerating the projectile in the bore of the gun, it was necessary to find the law of combustion of a charge of smokeless powder.

As this law is unknown, we deduce an empirical equation for the pressure, founded upon the data obtained from firings of the light gun and the 4.2-inch, and based upon the following considerations.

If the bore of the gun were sufficiently long to permit of the whole charge of smokeless powder being consumed, and if subsequently the powder gases expanded according to the adiabatic law; that is, so that they neither lost heat nor received heat from without,* then the pressures would vary in inverse ratio to the volume of the bore raised to the power 1.41.

As experiments demonstrate that charges of smokeless powders of the kinds experimented with by us continue to burn beyond the point for which the pressure reaches a maximum; and that beyond this point a gradual fall of pressures to the muzzle is to be observed, the pressure cannot be represented by an empirical monomial formula as may be done in the case of saltpetre-sulphur-charcoal powders.

To determine the pressure of smokeless powder gases at various points of the bore, we employ a formula made up of two factors, one of which has the form $\frac{1}{x^{1.4}}$, while the other is an infinite series in ascending inverted powers of x.

Accordingly we have,

$$P = \frac{a}{x^{1.4}}\left[1 + \frac{b}{x} + \frac{c}{x^2} + \ldots\ldots\right], \quad . \quad . \quad . \quad (1)$$

in which x is the distance of any section of the bore from the base of the bore; the volume of the powder chamber being given the reduced length corresponding to the diameter of the bore.

This form of expression fulfils the condition that pressures near the muzzle in long guns vary according to the law of adiabatic expansion as above enunciated.

The coefficients of equation (1) should fulfil one condition; namely, that for $x = x_m$, where x_m corresponds to the point of the bore for which the pressure is a maximum, the derivative of x for the pressure P should equate to zero; that is,

$$(P')_{x=x_m} = 0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

By formula (1) the pressures developed at sections of the bore in front of the point at which the maximum pressure occurs may be determined. Pressures that are developed between the origin of displacement of the projectile and the point of the bore at which the maximum pressure occurs cannot be determined by crusher gauges ranged along the sides of the bore.

To determine approximately the pressures in these latter portions of the bore we have employed the theoretical formulæ of Sarrau, as explained below in paragraph 6.

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* Insignificant losses in heating the walls of the gun, and in certain other ways are disregarded.

Having calculated the coefficients of equation (1) by the method of least squares, from the data obtained from firings of the light gun and the 4.2-inch, we find that to determine pressures within the limits of practical accuracy it is only necessary to preserve three terms of series (1). The differences between observed and calculated magnitudes thus found do not exceed the limits of errors which may occur in the quantities as due to method of measurement employed.

Placing

$$P=\frac{A}{x^{1.4}}+\frac{B}{x^{2.4}}+\frac{C}{x^{3.4}}, \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

differentiating for x and substituting for x, x_m, we obtain,

$$(P')_{x=x_m}=-1.4\frac{A}{x_m^{2.4}}-2.4\frac{B}{x_m^{3.4}}-3.4\frac{C}{x_m^{4.4}}=0,$$

whence,

$$C=-\frac{1.4}{3.4}x_m^2A-\frac{2.4}{3.4}x_mB, \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

and equation (3) takes the form

$$P=\frac{A}{x^{1.4}}\left(1-\frac{1.4}{3.4}\frac{x_m^2}{x^2}\right)+\frac{B}{x^{2.4}}\left(1-\frac{2.4}{3.4}\cdot\frac{x_m}{x}\right), \quad . \quad . \qquad (5)$$

or

$$P=\frac{a}{x^{1.4}}\left(1+\frac{b}{x}-\frac{c}{x^2}\right)^{*}, \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

where

$$a=A\,;\ b=\frac{B}{A}\ \text{and}\ c=\frac{1.4}{3.4}x_m^2+\frac{2.4}{3.4}x_m\frac{B}{A}. \quad . \quad . \qquad (7)$$

Calculations show that for the varieties of smokeless powders experimented with by us, the coefficient of the last term is subtractive, whence the minus sign is placed before c in (6).

5. Upon the basis of data obtained from firings of the light gun and the 4.2-inch, the coefficients of equation (6) have been calculated by the method of least squares, for all typical [†] cases

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[*] Pressures developed by saltpetre-sulphur-charcoal powders may be expressed by a similar formula, but the exponent 1.4 in the first factor must be reduced in magnitude to 1.2 or even 1.1.

[†] Upon firing reduced charges of smokeless powder from the light gun, pressures were evidently not registered with sufficient accuracy by the two

arising from firing charges of smokeless powders, and pressures have been determined by this formula for all points of the bore at which pressure gauges are placed.

The results obtained by experiment and by calculation are arranged in Tables I and II. Pressure curves have been constructed for Okhta smokeless powder tried in the light gun and the 4.2-inch and are shown in Plates I and II in broken lines.

We will illustrate, as an example, the manner of calculating the coefficients of equation (6) from data obtained from firing charges of Okhta smokeless powder (thickness of strip .035-inch) from the 4.2-inch gun employing a projectile of 39¾ lbs. weight.

In order to determine x corresponding to any point of the bore, it is necessary first of all to give to the powder chamber its reduced length corresponding to the diameter of the bore.

In the case of the 4.2-inch gun, it is therefore necessary to increase the distance of each point of the bore from the base of the bore by 6.68 inches.

Whence,

$$x_m = \frac{35.68}{4.2}\,;\ x_1 = \frac{40.28}{4.2}\,;\ x_2 = \frac{48.68}{4.2}\,;\ x_3 = \frac{59.88}{4.2}\,;$$

$$x_4 = \frac{68.48}{4.2}\,;\ x_5 = \frac{92.08}{4.2}\,;\ x_6 = \frac{134.08}{4.2}\,.$$

Corresponding to the above written magnitudes of x, we have the following observed pressures (Table II):

For x_m, a pressure of 1693 atmospheres
“ x_1, “ “ 1658 “
“ x_2, “ “ 1490 “
“ x_3, “ “ 1154 “
“ x_4, “ “ 872 “
“ x_5, “ “ 509 “
“ x_6, “ “ 323 “

Substituting these quantities in equation (5), we obtain the equations of condition, which, arranged in relative order of magnitude of coefficients, reduce to the form

gauges placed nearest the muzzle, and there were only three sets of observations left for calculating the coefficients in equation (5). This number was evidently insufficient for determining these coefficients within the limits of precision required.

$$u + v - 1 = 0,$$

$$\left.\begin{array}{l} 0.9709u + 0.9521v - 0.9793 = 0 \\ 0.8566u + 0.7784v - 0.8800 = 0 \\ 0.7031u + 0.5686v - 0.6816 = 0 \\ 0.6060u + 0.4494v - 0.5150 = 0 \\ 0.4229u + 0.2537v - 0.3006 = 0 \\ 0.2563u + 0.1135v - 0.1907 = 0 \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

where

$$u = \frac{A\,[\bar{2}.4687]}{1693} \text{ and } v = \frac{B\,[\bar{3}.2385]}{1693}.$$

The numbers enclosed in the brackets are logarithms.*

Denoting the coefficients of a by u, and the coefficients of v by b, and the indicated magnitudes of the unknown quantities by n, we form the normal equations

$$\left.\begin{array}{l} (aa)u + (ab)v - (an) = 0 \\ (ab)u + (bb)v - (bn) = 0 \end{array}\right\}, \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where $(aa) = 3.7823$; $(bb) = 3.1150$; $(ab) = 3.3997$;
$(an) = 3.6720$; $(bn) = 3.3342$.

Solving the normal equations, (9), we find

$$v = \frac{(bn\,.\,1)}{(bb\,.\,1)} = 0.56926, \dagger$$

and

$$u = -\frac{(ab)}{(aa)}v + \frac{(an)}{(aa)} = 0.45919.$$

Having calculated

$$A = u\,\frac{1693}{[\bar{2}.4687]} \text{ and } B = v\,\frac{1693}{[\bar{3}.2385]},$$

we assign, by (7), the coefficients in (6),

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right).$$

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* When minus signs are written over characteristics, the characteristics are to be taken as negative. Thus, following *our* notation, $\bar{2}$.4687 is to be read 8.4687—10.—J. B. B.

† In substituting the above values in (9) v is found 0.56696, instead of 0.56926, as given in the text. This minor error is here disregarded and the example allowed to stand in its original form.—J. B. B.

For the case under consideration

$\log a = 4.4220$; $\log b = 1.3235$ and $\log c = 2.1931$.

Substituting in the first two members of equation (8) the values found for u and v, and multiplying the sum of these terms by 1693, we obtain pressures for points of the bore corresponding to those at which pressure gauges are placed and where the pressures are measured. The calculated pressures are given in Table II, along with those obtained experimentally.

6. It was stated above that we had utilized the theoretical deductions of Sarrau in determining approximately the pressures developed in the bore from the origin of motion to the instant of development of maximum pressure, which occurs for that section of the bore (measured from the base of the bore) for which x has the value x_m. The manner of estimating pressures at these sections, and also the method of calculating initial velocities and times, are explained below, the solutions of these problems being interdependent.

In his memoir "Recherches Théoriques sur les Effets de la Poudre" 1874–1875, Sarrau has deduced the following differential equation of motion of a projectile in the bore of a gun,

$$(u + u_0)\frac{d^2u}{dt^2} + \theta\left(\frac{du}{dt}\right)^2 = f\frac{y}{M}, \quad . \quad . \quad . \quad . \quad (10)$$

where u represents the distance traversed by the projectile from the origin of motion,

M, the mass of the projectile,

f, the force of the powder,

y, the weight of the products of combustion which are generated in the instant of time, t,

$\theta = \frac{n - 1}{2}$, and n, the ratio of the specific heat of a gas at constant pressure to the specific heat of the gas at constant volume. For perfect gases $n = 1.4$; whence, $\theta = 0.2$.

$$u_0 = \frac{\tilde{\omega}}{s}\left(\frac{1}{\Delta} - \frac{1}{\delta}\right). \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$\tilde{\omega}$, the weight of the charge,

s, the area of cross section of the bore,

δ, the density of grain or strip of powder,

Δ, the density of loading.

Integrating the above differential equation (10) by approximative methods, Sarrau deduced expressions y_0, $\frac{dy_0}{dz}$, $\frac{d^2y_0}{dz^2}$, corresponding to the different values of z (see p. 87, Nouvelles Recherches sur le Effets de la Poudre dans les Armes, 1876).*

Through the aid of these expressions we may calculate with necessary accuracy the pressure of the gases, P, the velocity of the projectile, v, and the time, t, elapsed from the origin of motion of the projectile.

We have,

$$t = \frac{z}{K^\beta}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

$$v = u_0 K^\beta \frac{dy_0}{dz},$$

and the pressure

$$P = Mu_0 K^{2\beta} \frac{d^2y_0}{dz^2}.$$

If we denote by P_m and v_m the pressure and velocity corresponding to the section of the bore at the distance x_m from its base, then

$$P_m = Mu_0 K^{2\beta} \left(\frac{d^2y_0}{dz^2}\right)_m,$$

and

$$v_m = u_0 K^\beta \left(\frac{dy_0}{dz}\right)_m,$$

whence,

$$Mu_0 K^{2\beta} = \frac{P_m}{\left(\frac{d^2y_0}{dz^2}\right)_m},$$

and

$$u_0 K^\beta = \frac{v_m}{\left(\frac{dy_0}{dz}\right)_m}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13$$

therefore,

$$P = P_m \frac{\frac{d^2y_0}{dz^2}}{\left(\frac{d^2y_0}{dz^2}\right)_m} = m'P_m, \quad . \quad . \quad . \quad . \quad . \quad (14)$$

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* Proceedings of the U. S. Naval Institute, Whole No. 28, page 128. In these expressions z is the time in other units than seconds (see equation (54), page 108) and y_0 is travel (defined by equations (64) and (50)).—Ed.

and

$$v = v_m \frac{\dfrac{dy_0}{dz}}{\left(\dfrac{dy_0}{dz}\right)_m} = m'' v_m \,, \quad . \quad . \quad . \quad . \quad . \quad . \qquad (15)$$

where

$$m' = \frac{\dfrac{d^2 y_0}{dz^2}}{\left(\dfrac{d^2 y_0}{dz^2}\right)_m} \,, \quad \text{and} \quad m'' = \frac{\dfrac{dy_0}{dz}}{\left(\dfrac{dy_0}{dz}\right)_m} \,.$$

In order to develop a formula serving to determine the time, t, we must find first the quantity K^β from equation (13) and substitute it in (12).

We have,

$$K^\beta = \frac{v_m}{u_0} \frac{1}{\left(\dfrac{dy_0}{dz}\right)_m} \,,$$

and

$$t = \frac{u_0}{v_m} \left(\frac{dy_0}{dz}\right)_m . \, z \,.$$

Denoting the path of the shell from its origin of motion to the point corresponding to the maximum pressure of gases in the bore by u_m, we have (p. 55, Nouvelles Recherches) *

$$u_m = (y_0)_m u_0 \,,$$

whence,

$$u_0 = \frac{u_m}{(y_0)_m} \,,$$

and

$$t = \frac{u_m}{v_m} \frac{\left(\dfrac{dy_0}{dz}\right)_m}{(y_0)_m} . \, z = m''' \frac{u_m}{v_m} \,, \quad . \quad . \quad . \quad . \quad . \qquad (15)_1$$

where

$$m''' = \frac{\left(\dfrac{dy}{dz}\right)_m}{(y_0)_m} z \,.$$

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* This is an application of equation (50) in Whole No. 28, Proceedings U. S. N. I. The second member terms of equation 64, except the first, are omitted. (Pages 108 and 109, Proceedings.)—Ed.

Sarrau's tables (p. 91,* Nouvelles Recherches) show that the maximum pressure of the gases in the bore of the gun corresponds to $(y_0)_m = 0.6$. The deduced value of $\frac{d^2y_0}{dz^2}$ given in this table corresponds to magnitudes of y_0, differing by increments of 0.1.

Employing the tables taken from the above mentioned memoir, we calculate the coefficients m', m'' and m''', found in (14), (15) and $(15)_1$, for values of u differing by $\frac{u_m}{6}$.

The logarithms for these coefficients, arranged for convenience in computation, are given in the following table.

u	log m'	log m''	log m'''
$\frac{u_m}{6}$	$\bar{1}.8299$	$\bar{1}.4871$	0.3267
$2\frac{u_m}{6}$	$\bar{1}.9295$	$\bar{1}.6953$	0.4011
$3\frac{u_m}{6}$	$\bar{1}.9715$	$\bar{1}.8148$	0.4518
$4\frac{u_m}{6}$	$\bar{1}.9894$	$\bar{1}.8923$	0.4822
$5\frac{u_m}{6}$	$\bar{1}.9938$	$\bar{1}.9354$	0.5102
u_m	0.0000	0.0000	0.5332

In completion of the data coordinated in the above table we may add that for $u = 0$ the coefficients m', m'', and m''' also reduce to zero.

§ II.

WORK OF PRESSURE OF POWDER GASES, VELOCITIES OF PROJECTILE AND INTERVALS OF TIME.

7. The work performed by the powder gases, from that section of the bore at which the pressure reaches a maximum to the muzzle, is determined by the integral

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* Proceedings U. S. N. I. Whole No. 28, page 132.—Ed.

$$\int_{x_m}^{X} P dx = a \int_{x_m}^{X} \frac{1}{x^{1.4}} \left(1 + \frac{b}{x} - \frac{c}{x^2} \right) dx,$$

or,

$$\int_{x_m}^{X} P dx = \left\{ \frac{a}{0.4 x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2} \right) \right\}_{X}^{x_m}, \quad . \quad (16)$$

in which X represents the full length of the bore.

If P be given in atmospheres and x in calibres, then, in order to express the above integral in standard units of work, it is necessary to multiply it by the quantity $q.2R$, in which $2R$ denotes the calibre expressed in lineal units, and q, the pressure of one atmosphere on the area of the base of projectile and rifling, expressed in units of weight.

To represent the work of the powder gases over the distance u_m, from the origin of motion of the shell to the point of maximum pressure, we must estimate the magnitudes of the pressures in these parts by the method explained in the preceding section. We find in this way seven ordinates for determining the form of the curve of pressures, namely :

For $u = 0 \;\ldots\ldots\; P_0 = 0$

" $u = \frac{u_m}{6} \;\ldots\ldots\; P_1 = m'_1 P_m = 0.6759 \, P_m$,

" $u = 2\frac{u_m}{6} \;\ldots\ldots\; P_2 = m'_2 P_m = 0.8501 \, P_m$,

" $u = 3\frac{u_m}{6} \;\ldots\ldots\; P_3 = m'_3 P_m = 0.9365 \, P_m$,

" $u = 4\frac{u_m}{6} \;\ldots\ldots\; P_4 = m'_4 P_m = 0.9759 \, P_m$,

" $u = 5\frac{u_m}{6} \;\ldots\ldots\; P_5 = m'_5 P_m = 0.9858 \, P_m$,

" $u = u_m \;\ldots\ldots\; P_6 = P_m$.

Applying Simpson's rule of quadrature, we determine the work of pressure of the powder gases,

$$\int_0^{u_m} P dx = \frac{u_m}{6} \cdot \frac{1}{3} \{ P_0 + P_6 + 2 (P_2 + P_4) + 4 (P_1 + P_3 + P_5) \} = 0.8366 \, P_m \, u_m ;$$

whence the work performed by the powder gases over the distance u_m becomes

$$Q = 0.8366 \, . \, q P_m u_m \, , \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

where u_m is expressed in units of length.

8. By formula (5), pressures such as are measured with the aid of crusher gauges at various points of the bore are determined. Under the assumption that this formula represents a pressure on the base of the projectile during its motion through the bore of the gun, we have that the sum of the works of pressure of the powder gases, as determined by formulæ (16) and (17), will be the work expended in imparting accelerating and rotating impulses to the projectile, and in overcoming the friction of the rotating band against the rifling, neglecting the work spent in overcoming certain resistances, such as the resistance of the air to the motion of the projectile, etc.

Calling p the weight of the projectile, V the initial velocity, and g the acceleration of gravity, we have

$$(1 + \nu) \frac{p V^2}{2g} = \left\{ \frac{a}{0.4 x^{0.4}} \left(1 + \frac{0.4}{1.4} \, \frac{b}{x} - \frac{0.4}{2.4} \, \frac{c}{x^2} \right) \right\}_{X}^{x_m} q \, . \, 2R + Q. \quad (18)$$

where the calibre, $2R$, is expressed in the same lineal units as the velocity V, and q, the pressure of one atmosphere over the base of the projectile and rifling, is expressed in the same units as the weight of the projectile p.

The coefficient

$$\nu = \nu_1 + \nu_2 \, , \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where the quantity ν_1 depends on the part of the work of pressure expended in imparting rotation to the projectile, while ν_2 represents the portion of the work expended in overcoming friction of the rotating band against the rifling.

9. The quantity ν_1 is determined by the following method: If we denote by A the moment of inertia of the projectile about its axis of configuration and by ω its angular velocity of rotation at the muzzle, there is expended in imparting energy to it an amount of work equal to

$$\frac{\omega^2 A}{2} .$$

For elongated projectiles,

$$A = \mu \frac{p}{g} R^2 ,$$

where R represents half a calibre. The coefficient $\mu = 0.53$ for cast iron and armor-piercing projectiles of lengths of from 2.5 to 3.5 calibres. For projectiles of length from 3.5 to 4.0 calibres, $\mu = 0.55$; and $\mu = 0.60$ for thin-walled bursting shell.

Remembering that $\omega = \frac{2\pi V}{2\eta R}$, where η is the number of calibres the projectile must travel in order to make one complete turn, we have

$$\frac{\omega^2 A}{2} = \frac{p V^2}{2g} \mu \frac{\pi}{\eta^2} , \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

whence the coefficient

$$\nu_1 = \mu \frac{\pi^2}{\eta^2} . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

10. To determine the work expended in overcoming friction of the rotating band upon the rifling, formulæ for the pressure of the driving edge of the rifling against the rotating band of the projectile are required. The method of developing these formulæ is explained below.* Denoting by N the sum of the pressures taken in a direction perpendicular to the radius produced at the centre of the projections, we have the following equations of motion of the shell, in the direction of the axis of the bore and around the axis of configuration of the shell:

$$\frac{p}{g} \frac{d^2x}{dt^2} = qP - N(\sin\theta + f\cos\theta) , \quad . \quad . \quad . \quad (22)$$

$$A \frac{d\omega}{dt} = RN(\cos\theta - f\sin\theta) , \quad . \quad . \quad . \quad (23)$$

where f is the coefficient of friction, θ the angle between the spiral line of the rifling and the element of the bore, and qP the pressure of the grooves on the base of projectile, expressed in units of weight.

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* Formulæ relating to this subject are deduced in the lithographed Course of Interior Ballistics for the Michaelovsk Artillery Academy, by Lieutenant-Colonel Brynk.

When the projectile has passed a certain distance along the bore x, it has rotated through an angle φ, so that $y = R\varphi$, where y is the ordinate corresponding to the abscissa x and described upon the developed surface of the bore.

We have,

$$\frac{d^2y}{dt^2} = R\frac{d^2\varphi}{dt^2} = R\frac{d\omega}{dt},$$

whence,

$$\frac{d\omega}{dt} = \frac{d^2\varphi}{dt^2}.$$

Substituting the latter expression in (23), and putting $A = \mu\frac{p}{g}R^2$, we find,

$$\frac{p}{g}\frac{d^2\varphi}{dt^2} = \frac{N}{\mu R}(\cos\theta - f\sin\theta). \quad . \quad . \quad . \quad (24)$$

11. For rifling of uniform twist, we have

$$y = R\varphi = x\tan\theta,$$

$$\frac{d^2\varphi}{dt^2} = \frac{\tan\theta}{R}\frac{d^2x}{dt^2},$$

and equation (24) becomes

$$\frac{p}{g}\frac{d^2x}{dt^2} = N.\frac{1}{\mu}\frac{\cos\theta - f\sin\theta}{\tan\theta}. \quad . \quad . \quad . \quad (25)$$

Equating the second members of the last equation and (22), we have

$$N = qP\frac{\mu\tan\theta\sec\theta}{1 - f\tan\theta + \mu(\tan\theta + f)\tan\theta}. \quad . \quad . \quad (26)$$

As the angle θ and the coefficient f are small, we may neglect $f\tan\theta$ and $\tan^2\theta$ in comparison with unity and putting $\sec\theta = 1$, we obtain the approximate expression

$$N = \mu qP\tan\theta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

giving the value sought within the limits of requirements of practical accuracy.

12. Assuming an element of the bore as the axis of abcissæ and a line perpendicular to it through the vertex of the parabola as the axis of ordinates, we express the equation of parabolic rifling as developed on a plane surface,

$$y = k(b + u)^2 = R\varphi,$$

where b is the distance of the origin of the rifling from the vertex of the parabola, and u the distance of any section of the bore from the origin of rifling.

We have

$$R\frac{d\varphi}{dt} = 2k(b+u)\frac{du}{dt} = 2k(b+u)v,$$

$$\frac{d^2\varphi}{dt^2} = \frac{2k}{R}\left((b+u)\frac{d^2u}{dt^2} + v^2\right),$$

where v denotes the velocity of the projectile at the point corresponding to the abscissa $b+u$. Substituting this derived value of $\frac{d^2\varphi}{dt^2}$ in equation (24), we obtain

$$\frac{P}{g}\frac{d^2u}{dt^2} = \frac{N}{b+u}\frac{1}{\mu}\frac{\cos\theta - f\sin\theta}{2k} - \frac{p}{g}\frac{v^2}{b+u}.$$

Remembering that $\frac{d^2u}{dt^2} = \frac{d^2x}{dt^2}$, and equating the second member of the last and (22), we find

$$N = \frac{qP(b+u) + \frac{p}{g}v^2}{\frac{1}{\mu}\frac{\cos\theta - f\sin\theta}{2k} + (b+u)(\sin\theta + f\cos\theta)}. \quad . \quad . \quad (28)$$

For small values of θ we have

$$N = \mu q P\tan\theta + 2k\mu\frac{pv^2}{g}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

bearing in mind that

$$\tan\theta = \frac{dy}{du} = 2k(b+u).$$

13. The element of the work expended in overcoming the friction of the rotating band of the projectile over the rifling will be

$$fN\cos\theta\, dx,$$

or, θ being a small angle,

$$fNdx,$$

where x denotes the distance of any section of the bore from its base, expressed in calibres.

Substituting for N in this equation its value as given by formula (26), we obtain the work expended in overcoming the friction of the rotating band, for rifling of uniform twist.

$$fC\int_0^U qPdx, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

where

$$C = \frac{\mu \tan\theta \sec\theta}{1 - f\tan\theta + \mu(\tan\theta + f)\tan\theta},$$

or, approximately,

$$C = \mu \tan\theta,$$

U being the distance traversed by the projectile in the bore of the gun. Without sensible error, we may substitute for the integral in formula (30) the muzzle energy of the projectile; whence the work expended in overcoming friction becomes

$$fC\frac{pV^2}{2g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

Remembering that for parabolic rifling

$$\tan\theta = \frac{dy}{du} = 2k(b + u),$$

we may denote the work expended in overcoming the friction of the rotating band over the rifling by the expression (formula 29)

$$2f\mu k\int_0^U qP(b + u)\,dx + \frac{2pk}{g}f\mu\int_0^U v^2dx.$$

Having P and v as functions of x* we may determine the integrals found in the last formula either by integrating them directly or by calculating their values with the aid of quadrature formulæ, the quantities P and v^2 being expressed as functions of the variable x.

In view of the difficulty of calculating these quantities in the manner indicated, we deduce the following approximate method of determining the work expended in overcoming friction for the case under consideration.

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* The relation between the variables x and u is so simple that I have considered it unnecessary to introduce it.

For small values of θ we have $\cos\theta - f\sin\theta = 1$ and (formula 24)

$$\frac{p}{g}\frac{d^2\varphi}{dt^2} = \frac{N}{\mu R}.$$

Remembering that

$$\frac{d^2\varphi}{dt^2} = \frac{d\omega}{dt} \quad \text{and} \quad \omega = \frac{d\varphi}{dt},$$

we have

$$\frac{d^2\varphi}{dt^2} = \omega\frac{d\omega}{d\varphi},$$

and

$$\frac{p}{g}\,\omega d\omega = \frac{N}{\mu R}\,d\varphi.$$

Integrating the latter expression between the limits $\omega = 0$ and $\omega = \omega_U$; $\varphi = 0$ and $\varphi = \varphi_U$, we obtain, for rifling of uniform twist,

$$\frac{p}{2g}\,\omega_U^2 = \frac{1}{\mu R}\,N_c\varphi_U,$$

where N_c denotes the mean pressure of the rotating band upon the driving edge; whence, since $y_U = R\varphi_U = U\tan\theta$, we find

$$N_c = \frac{p\mu R^2}{2g}\frac{\omega_U^2}{y_U} = \frac{p\mu R^2}{2g}\frac{\omega_U^2}{U\tan\theta}. \quad . \quad . \quad . \quad (32)$$

We will apply this latter formula to the case of parabolic rifling. Having

$$y = k(b+u)^2,\ \tan\theta = 2k(b+u) \quad \text{and} \quad y = \frac{(b+u)\tan\theta}{2},$$

and denoting the ordinates corresponding to the origin of rifling and rifling at the muzzle by y_1 and y_2, and the inclinations of the rifling at the corresponding points by θ_1 and θ_2, we have

$$Y_U = y_2 - y_1.$$

If the ordinate y_1 corresponds to the abscissa b, then y_2 corresponds to $b + U$; therefore

$$y_2 = \frac{(U+b)\tan\theta_2}{2},\ y_1 = \frac{b\tan\theta_1}{2},$$

and

$$y_2 - y_1 = \tfrac{1}{2}\left(U\tan\theta_2 + b(\tan\theta_2 - \tan\theta_1)\right),$$

but since

$$\tan\theta_2 = 2k\,(U + b) \text{ and } \tan\theta_1 = 2kb\,,$$

we have

$$b = \frac{U\tan\theta_1}{\tan\theta_2 - \tan\theta_1}\,,$$

whence

$$Y_U = y_2 - y_1 = \frac{U}{2}\,(\tan\theta_2 + \tan\theta_1)\,.$$

Denoting the mean pressure of the rotating band of the projectile upon the driving edge of the rifling by N_c', we find (formula 32)

$$N_c' = \frac{p\mu R^2}{2g}\,\frac{2\,\omega_U^2}{U\,(\tan\theta_2 + \tan\theta_1)}\,,$$

or

$$N_c' = N_c\,\frac{2\tan\theta_2}{\tan\theta_2 + \tan\theta_1}\,. \quad . \quad . \quad . \quad . \quad . \quad . \qquad (33)$$

Remembering the preceding deduction (31), and making certain admissions, we obtain an approximate expression for the work expended in overcoming the friction of the rotating band against the parabolic rifling,

$$C'\frac{pV^2}{2g}\,, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (34)$$

where

$$C' = \frac{2f\mu\tan^2\theta_2\sec\theta_2}{1 - f\tan\theta_2 + \mu\,(\tan\theta_2 + f)\tan\theta_2}\cdot\frac{1}{\tan\theta_2 + \tan\theta_1}\,,$$

or (formula 27)

$$f\mu\,\frac{2\tan^2\theta_2}{\tan\theta_2 + \tan\theta_1}\,\frac{pV^2}{2g}\,.$$

Assuming the coefficient of friction as 0.2, we have

$$\left.\begin{aligned} \nu_2 &= C', \\ \text{or} \qquad \nu_2 &= f\mu\,\frac{2\tan^2\theta_2}{\tan\theta_2 + \tan\theta_1} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (35)$$

For rifling of uniform twist, θ_1 must be placed equal to θ_2 in the last expression.

14. We shall deduce expressions for calculating the velocity of the projectile at any section of the bore in front of that at which the maximum pressure is developed.

Let the abscissa x correspond to the section considered; then the work accomplished by pressure of the gases upon the base of the projectile, from this section of the bore to the muzzle, will be (formula 16)

$$\int_x^X P dx = \left\{ \frac{a}{0.4x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2} \right) \right\}_X^x .$$

This work is expended in imparting accelerating and rotating impulses to the projectile and in overcoming the friction of the rotating band over the rifling; whence

$$\frac{pV^2}{2g} - \frac{pv^2}{2g} = \frac{q \cdot 2R}{1 + \nu} \left\{ \frac{a}{0.4x^{0.4}} \left(1 + \frac{0.4}{1.4} \frac{b}{x} - \frac{0.4}{2.4} \frac{c}{x^2} \right) \right\}_X^x . \quad (36)$$

Denoting the second member of this equation by M, we obtain the expression

$$\frac{v}{V} = \sqrt{1 - \frac{2gM}{pV^2}} , \quad \ldots \ldots \quad (37)$$

suitable for calculating velocities of the projectile at various points along the bore. Velocities of the projectile, from the instant corresponding to the origin of motion to that at which the pressure reaches a maximum, may be determined approximately by formula (15) and by aid of the tables appended to paragraph 6.

15. We shall deduce expressions for determining the times of motion of the projectile in the bore of the gun, taking the point at which the pressure reaches a maximum as the origin.

Denoting by t' the elapsed time, reckoned from the instant the shell reaches the section of the bore corresponding to the maximum pressure, we have

$$dt' = 2R \cdot \frac{dx}{v} ,$$

where x is the distance of the section of the projectile from the base of the bore, expressed in calibres, and $2R$ the calibre, expressed in the same lineal units as the velocity v of the projectile.

Integrating this last expression between the limits $t' = 0$ and $t' = t'$, $x = x_m$ and $x = x$, we obtain

$$t' = 2R \int_{x_m}^{x} \frac{dx}{v} . \quad \ldots \ldots \ldots \quad (38)$$

We deduce v as a function of x from equation (36) of the preceding section. We have

$$v = V\sqrt{n_1 - \frac{n_2}{x^{0.4}} - \frac{n_3}{x^{1.4}} - \frac{n_4}{x^{2.4}}}, \quad . \quad . \quad . \quad (39)$$

where

$$n_1 = 1 + \frac{2Rq}{1+\nu}\cdot\frac{a}{0.4X^{0.4}}\left(1 + \frac{0.4}{1.4}\frac{b}{X} - \frac{0.4}{2.4}\frac{c}{X^2}\right)\frac{2g}{pV^2};$$

$$n_2 = \frac{2R.q}{1+\nu}\cdot\frac{a}{0.4}\frac{2g}{pV^2}; \quad n_3 = \frac{2Rq}{1+\nu}\cdot\frac{ab}{1.4}\frac{2g}{pV^2};$$

$$n_4 = -\frac{2R.q}{1+\nu}\frac{ac}{2.4}\frac{2g}{pV^2}.$$

Substituting in the integral (38) a second variable z for the independent variable, so chosen that $z = \frac{1}{x^{0.2}}$, we reduce the original integral to the form

$$t' = 2R\int_{x_m}^{x}\frac{dx}{v} = \frac{2R}{0.2}\cdot\frac{1}{V}\int_{z}^{z_m}\frac{dz}{z^6\sqrt{n_1 - n_2z^2 - n_3z^7 - n_4z^{12}}},$$

where the upper index z_m correponds to x_m.

The time t' is expressed by this solution in the form of an ultra-elliptic integral, the calculation of values of which is laborious; but in view of the simplicity of the calculation of the velocity v, by formula (37), we may very easily determine, and with sufficient practical accuracy, the time t' for values of the function $\frac{1}{v}$. In effecting this we employ the quadrature formula of the Academician P. L. Tchebisheff. For calculating intervals of time corresponding to a travel of projectile equal to one or two calibres, or to two or three calibres at the muzzle, all that is required is the determination of three or four values of the quantity $\frac{1}{v}$. By Tchebisheff's method, the value of the expression under the integral sign is calculated, not for equidistant intervals of path, but for intervals distributed as follows:

We have, from Tchebisheff's formula,

$$t_1' = 2R\int_{x'}^{x''} \frac{dx}{v} = \frac{l}{n}\left(\frac{1}{v_1} + \frac{1}{v_2} + \cdots\cdots + \frac{1}{v_n}\right).\, 2R, \qquad (39)_1$$

where $l = (x'' - x')$.

When $n = 3$, the velocities should be calculated

for $x_1 = x' + [\bar{1}.1666]\, l$
" $x_2 = x' + [\bar{1}.6990]\, l$
" $x_3 = x' + [\bar{1}.9313]\, l$

For $n = 4$, velocities should be calculated

for $x_1 = x' + [\bar{1}.0105]\, l$
" $x_2 = x' + [\bar{1}.6087]\, l$
" $x_3 = x' + [\bar{1}.7737]\, l$
" $x_4 = x' + [\bar{1}.9530]\, l$

The quantities in brackets are logarithms.

Times of movement of the projectile from the origin to the instant when the maximum pressure is developed in the bore may be determined approximately by formula $(15)_1$ with the aid of the tables given in paragaph 6.

16. The members of the second part of equation (18) were determined from coefficients of equation (6) that were calculated from firings of the light and the 4.2-inch guns.

Calculated results show that for most cases the value of the second member of the equation falls somewhat short of that of the energy of the projectile at the muzzle. The cause of this inequality was stated in paragraph 3.

In a succeeding paragraph will be explained a way by which it is found possible to compute pressures at various points along the bore under the assumption that the work performed by the powder gases exceeds the muzzle energy of the projectile by a certain determined quantity.

We will conclude the present section with an example—the calculation of the second member of equation (18) by utilization of data from the case discussed paragraph 5.

From the results of firings of the 4.2-inch gun with a charge of 4 lbs. 10 oz. of Okhta smokeless powder and a $39\frac{3}{4}$-lb. projectile, the coefficients in the equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)$$

were calculated as follows :

$$\log a = 4.4220 ;\ \log b = 1.3235, \text{ and } \log c = 2.1931.$$

In order to determine the second member of (18), it is necessary to know, besides the above data from paragraph 5, the distance u_m, the travel of the projectile from its seat to the point of maximum pressure; and the quantity q.

In the case under consideration, we have

$$u_m = 12.1 \text{ in. and } X = \frac{142.7}{4.2}.$$

The area of the base of the shell and rifling is 15.41 sq. in., whence, taking the pressure of one atmosphere as 16.278 lbs., we have

$$\log q = 2.37327,$$

and the calibre $2R = 4.2$ inches.

For convenience in computation we divide the second member of equation (18) by $\frac{pV^2}{2g}$.

Bearing the above data in mind, and placing $p = 39.75$ lbs., $V = 1796$ ft. and $P_m = 1742$, we have

$$\frac{2gQ}{pV^2} = 0.1743,$$

and

$$q.2R\left\{\frac{a}{0.4x^{0.4}}\left(1 + \frac{0.4}{1.4}\frac{b}{x} - \frac{0.4}{2.4}\frac{c}{x^2}\right)\right\}_X^{x_m}\frac{2g}{pV^2} = 0.7989;$$

whence the sum

$$0.1743 + 0.7989 = 0.9732$$

proves less than unity ; *i. e.*, the work performed by pressure of the powder gases is something less, as calculated, than the energy of the projectile, $\frac{pV^2}{2g}$, at the muzzle. The reason of this circumstance has been already explained.

§ III.

DETERMINATION OF CURVES OF PRESSURE, VELOCITY AND TIME, FROM MAXIMUM BORE PRESSURE AND MUZZLE ENERGY OF PROJECTILE.

17. From the formula for pressure given in paragraph 4, we may calculate the coefficients A and B in formula (5) when the maximum pressure in the bore and the muzzle energy of the projectile are given.

For the full solution of this question the form of rifling should be given in addition to the above, and the point for which the pressure is a maximum should be determined.

We may determine u_m approximately from an inspection of Tables I, II, III, IV and V.

Tables III and IV show that for coarse grained black powder the maximum pressure corresponds to a movement of the shell of about 2.65 in. = 0.77 calibre for the light gun, and to a distance of 4.1 in. = 0.98 calibre for the 4.2-inch; we find from Table V that for prismatic powder of density 1.69 the corresponding extent of travel is about 6.9 in. = 1.2 calibres for the 6-inch gun of 190 poods weight. When charges of smokeless powder are employed, the point of maximum pressure moves towards the muzzle. The following table shows the approximate values of u_m, as obtained from actual firing of smokeless powders under various conditions.

DESIGNATION OF GUN.	KIND OF POWDER.	u_m		MAXIMUM BORE PRESSURE.	LENGTHS OF POWDER CHAMBER.
		in.	calibres.	atmospheres.	in.
Light Gun.	Gun cotton.	9.65	2.82	about 1600	9.35
4.2-inch gun.	Gun cotton, thickness of strip .032 inch to .035 inch.	12.1	2.88	from 1700 to 1750	14.9
		14.1	3.36		16.9
		16.7	3.98	from 1000 to 1500	16.9
		16.6	3.95		12.4
	Gun cotton, thickness of strip .0425 inch to .045 inch.	16.7	3.98	from 1600 to 1700	16.9
		between 16.7 and 26.1	between 3.98 and 6.21	about 900	
	Rottweil nitro-glycerine.	8.3	1.98	about 1750	16.9
		12.1	2.88	about 1000	
6-inch gun.	Gun cotton and Rottweil nitro-glycerine.	17.9	3.0	from 1000 to 1850	24.9

It is evident from the above that as the breech pressure diminishes in the 4.2 gun, the section of the bore corresponding to the maximum pressure moves towards the muzzle. Although this circumstance is not so apparent in the cases of the light gun and the 6-inch, nevertheless, with charges of gun cotton powders developing breech pressures of from 1000 to 1300 atmospheres, the gauges placed directly in front of those giving the maximum readings (15.15 in. = 4.43 calibres for the light gun, and 23.3 in. = 3.9 calibres for the 6-inch gun) themselves afford readings which are close to the maxima; so it becomes evident that the actual maximum pressures developed correspond to sections of the bore between the two.

It follows from the above that for charges of gun cotton smokeless powders developing breech pressures of from 1600 to 1800 atmospheres, the maximum pressure in the bore occurs after the projectile has traversed a distance of from three to four calibres, according to the thickness of the powder strip; and that with reduced charges, a distance of from four to six calibres, according to the thickness of the powder strip; so that in the first case $u_m = 3$ or 4 calibres, and in the second, 4 or 6 calibres.

In the case of charges of nitro-glycerine powders experimented with in the 4.2 gun, u_m was found to be two calibres for full charges and 3 calibres for reduced charges. With the nitro-glycerine powders tried in the 6-inch gun $u_m = 3$ calibres for full and reduced charges; but the powder did not correspond to the length of the bore of the gun, nor were the charges completely consumed. Having the quantity u_m and the dimensions of the powder chamber, x_m in equation (5) may be calculated.

Sarrau has shown theoretically that the travel of the projectile from its seat to the point of maximum pressure in the bore is

$$u_m = 0.6 u_0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (A)$$

where u_0 is defined by formula (11), which we may express in the form

$$u_0 = l\left(1 - \frac{\Delta}{\delta}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (B)$$

where l denotes the reduced length of the powder chamber.

It is evident from the formulæ that u_m decreases with the decrease in weight of the charge, independently of variation in bore pressure and of kind of powder, which is contrary to experience obtained by practice.

Thus, for example, from (A) and (B) we find, for a charge of 4 lbs. 15 oz. of the Okhta smokeless powder, in the 4.2-in. gun,

$$u_m = 11.1 \text{ in.},$$

and for $5\frac{3}{4}$ pounds of an Okhta powder specially designed for the same gun,

$$u_m = 10.4 \text{ in.},$$

while for the latter case actual firings prove that

$$u_m = 16.7 \text{ in.},$$

which is greater than the result practically obtained for 4 lbs. 15 oz. of the Okhta powder, which gives

$$u_m = 12.1 \text{ in.}$$

In view of the nature of results above considered, this might have been expected.

It was stated above that with the diminution of weight of charge and consequently with diminution in magnitude of pressure, the quantity u_m increased for one and all varieties of powder; but it is easy to see that while the values calculated by formulæ (A) and (B) increase with diminution of charge, they do not do so in the degree that practice determines them to do.

Thus, for example, the charge of 3 lbs. 11 oz. of Okhta smokeless powder, fired from the 4.2-inch gun, gives by calculation

$$u_m = 12.0 \text{ in.},$$

which is greater than for the charge of 4 lbs. 15 oz., but markedly less than the practically determined value

$$u_m = 16.7 \text{ in.}$$

Firing projectiles of different weights from the 4.2-in. gun, with the same charge of $4\frac{60}{96}$ lbs. of Okhta smokeless powder proves that with the diminution of these weights the maximum pressure diminishes, and that at the same time the section of the bore corresponding to the maximum pressure moves towards the muzzle; that is, u_m increases. But by formulæ (A) and (B) the quantity u_m should, under existing conditions, remain unaltered.

As the result of practical trial, and from the nature of the question under consideration, it follows that the value of u_m depends on the maximum bore pressure, the weight of the charge, the dimensions of the strip and the particular properties of the powder under consideration. The number of experimental results obtained up to the present is not sufficient to permit of the nature of this relation being definitely expressed.

18. To determine the pressure curve, as defined by formula (5),

$$P = \frac{A}{x^{1.4}}\left(1 - \frac{1.4}{3.4}\left(\frac{x_m}{x}\right)^2\right) + \frac{B}{x^{2.4}}\left(1 - \frac{2.4}{3.4}\frac{x_m}{x}\right), \quad . \quad (5)$$

the coefficients (A) and (B) must be found, and for determining these, two equations are required. We may obtain one of these equations from (5) by putting $x = x_m$ and substituting for P its corresponding value $P = P_m$. This pressure may, without sensible error, be assumed as equal to the breech pressure. The quantity x_m is the reduced length of the powder chamber corresponding to a diameter equal to the calibre of the gun, and increased by the distance u_m. This latter quantity is determined under the conditions stated in the preceding section.

We have, then,

$$P_m = \frac{A}{x_m^{1.4}}\left(1 - \frac{1.4}{3.4}\right) + \frac{B}{x_m^{2.4}}\left(1 - \frac{2.4}{3.4}\right). \quad . \quad . \quad (40)$$

The second equation for the determination of (A) and (B) is supplied by the condition that the work developed by pressure is equal to $(1 + \nu)\frac{p V^2}{2g}$; that is,

$$(1 + \nu)\frac{p V^2}{2g} = q \, . \, 2R\int_{x_m}^{X} P dx + Q,$$

where Q is determined by formula (17).

Integrating the first part of the second member of the last equation by substituting for P its value from (3), we have

$$\int_{x_m}^{X} P dx = \int_{x_m}^{X}\left(\frac{A}{x^{1.4}} + \frac{B}{x^{2.4}} + \frac{C}{x^{3.4}}\right) dx$$

$$= \left(\frac{A}{0.4 x^{0.4}} + \frac{B}{1.4 x^{1.4}} + \frac{C}{2.4 x^{2.4}}\right)_{X}^{x_m};$$

but (formula 4),

$$C = -\frac{1.4}{3.4}\,x_m^2 A - \frac{2.4}{3.4}\,x_m B\,,$$

whence

$$\int_{x_m}^{X} P dx = \left\{ \frac{A}{0.4x^{0.4}}\left(1 - \frac{0.4}{2.4}\,\frac{1.4}{3.4}\left(\frac{x_m}{x}\right)^2\right) + \frac{B}{1.4x^{1.4}}\left(1 - \frac{1.4}{2.4}\,\frac{2.4}{3.4}\,\frac{x_m}{x}\right)\right\}_{X}^{x_m},$$

and

$$(1 + \nu)\frac{pV^2}{2g} = q\,.\,2R\left\{ \frac{A}{0.4x^{0.4}}\left(1 - \frac{0.4}{2.4}\,\frac{1.4}{3.4}\left(\frac{x_m}{x}\right)^2\right) + \frac{B}{1.4x^{1.4}}\left(1 - \frac{1.4}{3.4}\,\frac{x_m}{x}\right)\right\}_{X}^{x_m} + Q, \quad . \quad . \quad (41)$$

where

$$\left.\begin{array}{c} \nu = \nu_1 + \nu_2 \\ \nu = \mu\tan^2\theta_2, \text{ and } \nu_2 = C' \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad (42)$$

Solving (40) and (41), we find A and B, and then, by substituting them in (5), we are enabled to ascertain the pressures at various points along the bore.

For convenience in computation, equations (40) and (41) may be expressed by use of the abbreviations

$$\left.\begin{array}{c} \alpha = \dfrac{[\bar{1}.76956]}{P_m\,x_m^{1.4}}\,;\ \beta = \dfrac{[\bar{1}.46853]}{P_m\,x_m^{2.4}} \\ \alpha' = \dfrac{2g}{pV^2}\cdot\dfrac{1}{0.4}\left\{\dfrac{1}{x^{0.4}}\left(1 - [\bar{2}.83650]\left(\dfrac{x_m}{x}\right)^2\right)\right\}_{X}^{x_m} q.2R \\ \beta' = \dfrac{2g}{pV^2}\,\dfrac{1}{1.4}\left\{\dfrac{1}{x^{1.4}}\left(1 - [\bar{1}.61465]\left(\dfrac{x_m}{x}\right)\right)\right\}_{X}^{x_m} q.2R \\ \gamma = 1 + \nu - \dfrac{2gQ}{pV^2}, \end{array}\right\} \quad . \quad (43)$$

where the numbers included in brackets represent logarithms.

By the use of the substitutions indicated, equations (40) and (41) assume the form

$$\left.\begin{array}{l} \alpha A + \beta B = 1 \\ \alpha' A + \beta' B = \gamma \end{array}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (44)$$

where

$$\left.\begin{array}{l} A = \dfrac{\beta' - \gamma\beta}{\alpha\beta' - \alpha'\beta} = \dfrac{\gamma\left(\dfrac{\beta}{\beta'}\right) - 1}{\alpha'\left(\dfrac{\beta}{\beta'}\right) - \alpha} \\[4ex] B = \dfrac{\alpha\gamma - \alpha'}{\alpha\beta' - \alpha'\beta} = \dfrac{\dfrac{\alpha'}{\beta'} - \gamma\left(\dfrac{\alpha}{\beta'}\right)}{\alpha'\left(\dfrac{\beta}{\beta'}\right) - \alpha} \end{array}\right\} \quad . \quad . \quad . \quad . \quad (45)$$

19. We shall apply the above formulæ to the determination of curves of pressures, velocities and times in the following examples.

Example 1.—It is found by trial that the pressure in the bore of the 4.2-inch gun with a charge of 4 lbs. 10 oz. of Okhta smokeless powder (thickness of strip .035 in.) attains its maximum at a distance corresponding to a travel of projectile of 12.1 inches. The pressure at this section of the bore is $P_m = 1742$ atmospheres. Under these conditions there is obtained the initial velocity $V = 1796$ f. s.; the projectile weighing 39.75 lbs.

The length of the powder chamber is 16.9 inches. The rifling of the 4.2-inch gun is parabolic, with a twist of one in twenty-five calibres at the muzzle and one in seventy-four and six-tenths at the origin of rifling. For the cast iron projectiles used in the trials, $\mu =$ 0.53 inches.

To calculate the coefficient ν, we have

$$\nu_1 = \mu \tan^2 \theta_2 = 0.53 \left(\frac{\pi}{25}\right)^2 = 0.00837,$$

$$\nu_2 = C' = \frac{2f\mu \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu (\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.02020,$$

$$\nu = 0.02857.$$

It was shown in paragraph 5 that, in order to obtain the reduced length of any section of the bore of the 4.2-inch gun, it was necessary to increase the length of the powder chamber by 6.68 inches, the compensation for the reduced length of the powder chamber with its slope. Therefore

$$x_m = \frac{16.9 + 12.1 + 6.68}{4.2}$$

$$X = \frac{142.7}{4.2}.$$

The value of q for the 4.2-inch was calculated in paragraph 16 as

$$\log q = 2.37327.$$

Substituting the above data in the formulæ of the preceding number, we calculate

$$\log \alpha = \bar{5}.22767;\ \log \beta = \bar{7}.99747;$$

$$\log \alpha' = \bar{5}.20040;\ \log \beta' = \bar{7}.83372;$$

$$\frac{2gQ}{pV^2} = 0.17434;\ \gamma = 1.02857 - 0.17434 = 0.85423;$$

$$\log \gamma = \bar{1}.93158;$$

$$\log A = 4.59401;\ \log B = 5.52971.$$

Having ascertained A and B, we may calculate pressures at various points along the bore by formula (5).

To employ this formula, we reduce it to the form

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right); \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

and, by relation (7), we obtain the coefficients in the equation

$$\log a = 4.59401,$$

$$\log b = 0.93570,$$

$$\log c = 1.91078.$$

For determining velocities, we employ the expression

$$(1 + \nu)\left(\frac{pV^2}{2g} - \frac{pv^2}{2g}\right) = \left\{\frac{[4.9919]}{x^{0.4}}\left(1 + \frac{[0.3917]}{x} - \frac{[1.1327]}{x^2}\right)\right\}_X^{x_m} q \, . \, 2R.$$

The time t' is determined by formula $(39)_1$ of paragraph 15.

Denoting by t_m the time of movement of the projectile, from the instant of its displacement to the instant at which the maximum pressure is developed in the bore, we have

$$t = t_m + t',$$

as measured from the origin of motion. The time t_m is determined by formula $(15)_1$ of paragraph 6.

The pressures, velocities and times contained in the following table are calculated by utilization of the preceding formulæ. The observed pressures and initial velocities are added.

Distance of Section of Bore from Base of Bore.	Pressures.		Calculated Velocities.	Calculated Times.
	Observed.	Calculated.		
in.	atm.	atm.	ft. sec.	sec.
29.0	1693	1742*	739	0.00468
33.6	1658	1681	891	0.00515
42.0	1490	1447	1093	0.00586
53.2	1154	1147	1286	0.00665
61.8	872	965	1388	0.00719
85.4	509	637	1582	0.00851
127.4	323	363	1775	0.01051
136.0		334	1796	0.01099

The above table shows that the calculated pressures exceed the actual pressures only for those gauges placed in the portions of the bore nearest the muzzle, a result that might have been expected from what has been said above. The curves for pressures, velocities and time intervals are shown in Plate I, the pressure curve being denoted by the broken line. Those portions of the curve extending from the origin of motion to the point corresponding to

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* The maximum pressure is assumed as identical with that calculated by use of formula (5). It is approximately equal to the registered breech pressure of 1722 atmospheres.

the maximum pressure are determined by ordinates whose values are calculated by the use of the formulæ and table contained in paragraph 6.

Example II.—It is experimentally ascertained that the pressure in the bore of the 3.42-inch gun, with a charge of 1 lb. 11 oz. of Okhta smokeless powder attains its maximum for a travel of the projectile of 9.65 inches, P_m then being 1660 atmospheres. Under these conditions an initial velocity $V = 1673$ feet is obtained, the projectile weighing 16.75 lbs. The length of the powder chamber is 9.35 inches.

The rifling of the 3.42-inch gun is of progressive curvature, one turn in 40 calibres at the muzzle and one turn in 370 calibres at the origin; $\mu = 0.53$ for the projectile used.

To calculate the coefficient ν, we have

$$\nu_1 = \mu \tan^2 \theta_2 = 0.53 \left(\frac{\pi}{40}\right)^2 = 0.00327,$$

$$\nu_2 = C' = \frac{2f\mu \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.01514,$$

and

$$\nu = 0.01841.$$

In expressing the distance of any section of the bore from the base of the bore, it is necessary to increase the distance measured along the axis of the gun by 2.36 inches (compensation for "reduced length").

Therefore

$$x_m = \frac{9.35 + 9.65 + 2.36}{3.425}$$

and

$$X = 22.11 \text{ calibres.}$$

The area of cross section of shell and rifling is 9.640 sq. in.,

$$\log q = 2.19568.$$

By the formula of the preceding section, we find

$$\log \alpha = \bar{5}.43653; \quad \log \beta = \bar{6}.34056;$$

$$\log \alpha' = \bar{5}.39025; \quad \log \beta' = \bar{6}.17165;$$

$$\frac{2gQ}{pV^2} = 0.24085\,;\ \gamma = 1.01841 - 0.24085 = 0.77756\,;$$

$$\log \gamma = \bar{1}.89073\,;$$

$$\log A = 4.21931\,;\ \log B = 5.39882.$$

The coefficients in equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right) \quad . \quad . \quad . \quad . \quad . \quad (6)$$

become

$$\log a = 4.21931,$$
$$\log b = 1.17951,$$
$$\log c = \bar{1}.91682.$$

For determining the velocity of the projectile we have the expression

$$\frac{PV^2}{2g} - \frac{pv^2}{2g} = \left\{\frac{[4.6172]}{x^{0.4}}\left(1 + \frac{[0.6349]}{x} - \frac{[1.1387]}{x^2}\right)\right\}_X^{x_m} \frac{q.2R}{1+\nu}.$$

Formulæ $(15)_1$ and $(39)_1$ serve to determine the times of motion of the projectile at points along the bore.

The calculated results are given in the following table:

Distance of Section of Bore from Base of Bore.	Pressures.		Calculated Velocities.	Calculated Times.
	Observed.	Calculated.		
in.	atm.	atm.	ft. sec.	sec.
19.0	1588	1660*	813	0.00338
24.5	1489	1468	1045	0.00387
34.5	1063	996	1300	0.00458
48.0	441	633	1492	0.00539
66.5	307	384	1636	0.00637
73.4		329	1673	0.00672

The deductions to be made from this table are identical with those to be had from Example I.

The curves of pressures, velocities and times are shown in Plate II, the pressure curve being denoted by the broken line. Those

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* This pressure is assumed as identical with that given by formula (5).

portions of the curve extending from the seat of the projectile to the point of maximum pressure were determined as explained in paragraph 6.

Example III.—Upon firing a charge of 12 lbs. of Okhta smokeless powder from the 6-inch gun of 190 poods weight (7600 lbs.), a maximum pressure $P_m = 1798$ atm. was realized, which corresponded to a travel of projectile along the bore of 17.9 inches. The initial velocity $V = 1835$ ft. sec. It is required to determine the curves of pressure, velocities and intervals of time. The projectile weighed 81.25 lbs. and the length of the powder chamber was 24.9 inches. The rifling of the gun is parabolic, the inclination at the muzzle being $\theta_2 = 4°$ (one turn in 45 calibres) and at the origin of rifling $\theta_1 = 1° 47'$.

$\mu = 0.53$ for the 6-inch cast iron projectile of 2.5 calibres' length. Therefore

$$\nu_1 = \mu \tan^2 \theta_2 = 0.53 \tan^2 4° = 0.002591,$$

$$\nu_2 = C' = \frac{2\mu f \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.01030,$$

and

$$\nu = \nu_1 + \nu_2 = 0.01289.$$

In expressing the distance of any section of the bore from the base of the bore, the distance as measured along the axis of the gun must be increased by 2.15 inches, so as to make the reduced length of the powder chamber and slope correspond to a diameter of chamber equal to that of the bore. We then have

$$x_m = \frac{24.9 + 17.9 + 2.15}{6},$$

and

$$X = \frac{114 + 2.15}{6} = 19.36 \text{ calibres.}$$

The area of the base of the projectile and rifling is 29.88 sq. in.,

$$\log q = 2.67220.$$

By the formula of the preceding number, we find

$$\log \alpha = \bar{5}.29036; \ \log \beta = \bar{6}.11475;$$

$$\log \alpha' = \bar{5}.19683; \ \log \beta' = \bar{7}.93578;$$

$$\frac{2gQ}{pV^2} = 0.24842; \quad \gamma = 1.01189 - 0.24842 = 0.76347;$$

$$\log \gamma = \bar{1}.88279;$$

$$\log A = 4.55654; \quad \log B = 5.35821.$$

The coefficients in equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)$$

become

$$\log a = 4.55654,$$
$$\log b = 0.80167,$$
$$\log c = 1.75286.$$

To determine the velocities of projectile, we employ

$$\frac{pV^2}{2g} - \frac{pv^2}{2g} = \left\{ \frac{[4.9544]}{x^{0.4}}\left(1 + \frac{[0.2577]}{x} - \frac{[0.9748]}{x^2}\right) \right\}_{x}^{x_m} \frac{q \,.\, 2R}{1 + \nu},$$

Formulæ $(15)_1$ and $(39)_1$ are used to determine the times of movement of the projectile along the bore.

Calculated results are arranged in the following table:

Distance of Section of Bore from Base of Bore.	Calculated.		Calculated Times.
	Pressures.	Velocities.	
in.	atm.	ft. sec.	sec.
42.8	1798	910	0.00560
48.2	1744	1059	0.00605
57.0	1551	1246	0.00669
63.0	1411	1358	0.00707
72.0	1216	1485	0.00760
79.6	1103	1572	0.00802
93.0	883	1696	0.00870
110.0	703	1812	0.00953
114.0	667	1835	0.00971

Curves of pressures, velocities and intervals of time are traced in Plate III. The ordinates of these curves, from the origin of motion to the point corresponding to maximum pressure in bore, are calculated by the use of the table and the formula given in paragraph 6. The measured pressures are also shown upon this sheet.

20. In designing guns, it is necessary to have some way of estimating the pressure of the powder gases at various points along the bore. The method herein described may be employed as an approximate solution of the question, when the breech pressure and muzzle energy of the projectile are given and the form of rifling is stated.

The form of rifling is required for the calculation of the coefficient ν. Assuming the maximum bore pressure P_m as equal to the pressure at the breech, and determining approximately the section of the bore corresponding to this maximum pressure (paragraph 17), we obtain the full data for the solution of the question within the prescribed limits.

Having developed the curve of pressures, the opposing resistances of the gun, which should be distributed according to load, may be calculated. With us it is customary to make the strength of resistance equal to one and one half times the load; and in the case of heavy guns, twice the load.

We shall proceed to apply the above explained method to the determination of curves of pressures, velocities and intervals of time in the case of a gun for which pressures have not been determined by means of gauges ranged along the bore.

Example IV.—As the result of trials made by us with a 6-in. Q. F. Canet gun of 50 calibres' length, we find a breech pressure of 2250 atmospheres, corresponding to an initial velocity $V = 2620$ ft. sec., the weight of the projectile being 101 lbs. Such results may be obtained by employing a charge of about $27\frac{1}{2}$ lbs. of Okhta smokeless powder. The curves of pressures, velocities and times are required.

The length of the powder chamber is 40.44 in.; the rifling of this gun is parabolic, the angle of inclination at the muzzle being $\theta_2 = 6°$, and the initial angle $\theta_1 = 2° 30'$. The cast iron projectile for the Canet gun has a length of about $3\frac{1}{2}$ calibres, and $\mu = 0.55$.

Therefore

$$\nu_1 = \mu \tan^2 \theta_2 = 0.00607,$$

$$\nu_2 = C' = \frac{2\mu f \tan^2 \theta_2 \sec \theta_2}{1 - f \tan \theta_2 + \mu(\tan \theta_2 + f) \tan \theta_2} \cdot \frac{1}{\tan \theta_2 + \tan \theta_1} = 0.01712\ ,$$

and

$$\nu = \nu_1 + \nu_2 = 0.02319.$$

On the basis of the conditions stated in paragraph 17, we assume that the maximum bore pressure P_m equals the breech pressure of 2250 atmospheres and is developed in the bore at a point corresponding to a travel of the projectile of four calibres; *i. e.*, $u_m = 24$ inches.

In expressing the distance of any section of the bore from the base of the bore, it is necessary to increase the distance measured along the axis by 3.31 inches, so as to give powder chamber and slope the reduced length corresponding to a diameter of chamber equal to the calibre of the gun. Whence

$$x_m = \frac{40.44 + 24 + 3.31}{6}\ ,$$

and

$$X = \frac{281.34 + 3.31}{6} = 47.44 \text{ calibres.}$$

The area of the base of the projectile and rifling is 28.79 sq. in.,

$$\log q = 2.67084.$$

We find from the formulæ given above

$$\log \alpha = \bar{6}.94352\ ;\ \log \beta = \bar{7}.58973\ ;$$

$$\log \alpha' = \bar{6}.88352\ ;\ \log \beta' = \bar{7}.38762\ ;$$

$$\frac{2gQ}{pV^2} = 0.16396\ ;\ \gamma = 1.02319 - 0.16396 = 0.85923\ ;$$

$$\log \gamma = \bar{1}.93411\ ;$$

$$\log A = 5.03497\ ;\ \log B = 5.09396.$$

The coefficients in equation

$$P = \frac{a}{x^{1.4}}\left(1 + \frac{b}{x} - \frac{c}{x^2}\right)$$

become

$$\log a = 5.03497\,,$$
$$\log b = 0.05899\,,$$
$$\log c = 1.78980\,.$$

To determine velocities of projectile, we employ the expression

$$\frac{pV^2}{2g} - \frac{pv^2}{2g} = \left\{ \frac{[5.4329]}{x^{0.4}}\left(1 + \frac{[\bar{1}.5150]}{x} - \frac{[1.0118]}{x^2}\right)\right\}_{X}^{x_m} \frac{q \,.\, 2R}{1+\nu}\,.$$

The times of motion of projectile along the bore are calculated by formulæ $(15)_1$ and $(39)_1$.

Calculated results are given in the following table.

Distance of Section of Bore from Base of Bore.	Calculated Pressures.	Calculated Velocities.	Calculated Times.
in.	atm.	ft. sec.	sec.
40.44	0	0	0
44.44	1521	322	0.00405
48.44	1918	520	0.00480
52.44	2138	684	0.00540
56.44	2196	818	0.00579
60.44	2218	903	0.00618
64.44	2250	1048	0.00651
78.00	2113	1351	0.00745
84.92	1994	1473	0.00787
96.00	1799	1639	0.00846
110.90	1558	1816	0.00914
132.00	1284	2006	0.01006
159.41	1023	2186	0.01115
204.00	746	2394	0.01277
281.34	486	2620	0.01533

Curves of pressures, velocities and times are shown in Plate IV. The upper broken line shown upon this plate represents the strength of resistance of the gun, calculated for a limit of elasticity of 3300 atmospheres.

§ IV.

PRESSURE OF THE DRIVING EDGE OF THE RIFLING UPON THE ROTATING BAND OF THE PROJECTILE.

21. Having determined the pressures of the powder gases and the velocities of the projectile for various points along the bore, we may ascertain the pressure of the rifling upon the rotating band of the projectile, if the equation to the curve of rifling, developed upon a plane surface, be given.

In paragraph 12 we developed formulæ suitable for determining, within the required limits of accuracy, the pressures of rifling upon rotating band in the case of parabolic rifling, (formula (29)).

$$N = \mu q P \tan\theta + 2k\mu \frac{pv^2}{g}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

N in this formula is expressed in the same units of weight as the weight of the projectile p; the bore pressures are expressed in atmospheres, q representing the pressure of one atmosphere over the base of the projectile and rifling, taken in units of weight.

Assuming the prolongation of the bore as the axis of abscissæ and a line perpendicular to it through the vertex of the parabola as the axis of ordinates, Y, we obtain the equation of parabolic rifling developed upon a plane,

$$y = k(b + u)^2,$$

where b is the distance of the origin of rifling from the vertex of the parabola, and u the distance of any section of the bore from the origin of rifling.

The quantities b and u are expressed in the same lineal units as the velocity v and the acceleration of gravity g.

Remembering that

$$\tan\theta = 2k(b + u),$$

and substituting this last expression in formula (29), we obtain

$$N = 2k\mu q P(b + u) + 2k\mu \frac{pv^2}{g}. \quad . \quad . \quad . \quad . \quad . \quad (46)$$

Employing the data given in paragraph 19, we may calculate the pressures N upon the rotating band of the projectile in the case of the 4.2 inch gun. As supplementary to the data there found, we state that

$$k = 0.0040259, \text{ and } b = 5.68 \text{ ft.};$$

the distance of the origin of rifling from the base of the bore is 17.17 in.; the angle of inclination of rifling at the origin is $\theta_0 = 2° 38'$, and at the muzzle $\theta_1 = 7° 10'$.

Calculated results are shown in the following table:

Distance of Section of Bore from Base of Bore.	Bore Pressures P.	Velocities of Projectile v.	Pressures upon the Driving Edge of Projectile N.
in.	atm.	ft. sec.	tons.
29.0	1742	739	5.89
33.6	1681	891	6.49
42.0	1447	1093	7.09
53.2	1147	1286	7.55
61.8	965	1388	7.77
85.4	637	1582	8.26
115.5	421	1727	8.71
127.4	363	1775	8.89
136.0	334	1796	8.96

It is evident from the above table that the pressure N increases as the projectile moves along the bore and attains its greatest value at the muzzle.

In Plate I is traced the curve of pressures N, upon the rotating band, from the origin of motion of the projectile to the point corresponding to the maximum bore pressure, the pressures from the origin of motion to the point of maximum pressure being calculated for values of P and v determined by the formulæ and table of paragraph 6.

The initial angle of inclination of the rifling of the 4.2-inch gun is determined under the condition that the pressure N upon the rotating band shall be approximately equal for its values as developed at the point of maximum pressure in the bore and at the muzzle of the gun, for charges of coarse grained powder developing breech pressures of 1900 atmospheres, with projectile of $39\frac{3}{4}$ lbs. weight, and initial velocity of 1450 f. s. Under these conditions $N_m = 5.2$ tons at the point of maximum pressure, and $N_1 = 5.7$ tons at the muzzle.

The differences between the pressures upon the rotating band of the projectile at the origin of rifling and at the muzzle will be found still greater if we consider the results abtained with a charge of $5\frac{3}{4}$ lbs. of Okhta smokeless powder specially prepared for the 4.2-in. gun (thickness of strips .0425 in.). We then find for the section of the bore at which the pressure reaches its maximum

$$P_m = 1709 \text{ atm.}, \; v_m = 845 \text{ ft. sec., and } N_m = 6.4 \text{ tons},$$

and at the muzzle

$$P_1 = 467 \text{ atm.}, \; V = 1962 \text{ ft. sec., and } N_1 = 11.1 \text{ tons}.$$

If the rifling were of constant curvature, of 25 cal. twist, that is, if $\theta = 7° \, 10'$, then the greatest value of N would be found at the section of the bore corresponding to the maximum pressure.

Taking $P = 1709$ atmospheres, we have

$$N = q\mu P \tan\theta = 10.8 \text{ tons}.$$

Results show that the maximum pressure upon the rotating band is less for rifling of constant curvature than it is for parabolic rifling, according to results obtained from firing charges of $5\frac{3}{4}$ lbs. of Okhta smokeless powder. The disadvantage of progressive rifling for progressive powders arises from the fact that the initial angle of inclination of the rifling is not adapted to the conditions of the problem. The manner of determining this angle is explained below.

22. The initial angle of inclination of rifling is customarily determined under the condition that the pressure upon the rotating

band of the projectile N_m, at the point of the bore corresponding to the maximum powder pressure P_m, should be equal to the pressure upon the rotating band N_1, at the muzzle.* Denoting the angle of inclination of the rifling for the point of maximum bore pressure P_m, as θ_m, the distance of the corresponding section of the bore from the base of the bore by U, and the inclination of the rifling at the muzzle by θ_1, and remembering that

$$2k = \frac{\tan\theta_1 - \tan\theta_m}{U},$$

we obtain (formula (29)),

$$N_m = q\mu P_m \tan\theta_m + \mu \frac{p}{g} v^2_m \frac{\tan\theta_1 - \tan\theta_m}{U},$$

$$N_1 = q\mu P_1 \tan\theta_1 + \mu \frac{p}{g} V^2 \frac{\tan\theta_1 - \tan\theta_m}{U}.$$

Equating the second members of the last two equations and solving for $\tan\theta_m$, we obtain

$$\tan\theta_m = \frac{P_1 q + \frac{pV^2}{gU}\left(1 - \frac{v^2_m}{V^2}\right)}{P_m q + \frac{pV^2}{gU}\left(1 - \frac{v^2_m}{V^2}\right)} \tan\theta_1 \quad . \quad . \quad . \quad (47)$$

For a charge of 4 lbs. 10 oz. specially prepared Okhta smokeless powder, we have

$$P_m = 1742 \text{ atm.};\quad V_m = 739 \text{ ft. sec.};$$

$$P_1 = 334 \text{ atm., and } V = 1796 \text{ ft. sec.}$$

The pressure P_m occurs at a point 29 inches distant from the base of the bore, its whole length being 136 inches; whence $U = 136 - 29 = 107$ in.

Substituting the above quantities in equation (47) and remembering that $p = 39\frac{3}{4}$ lbs., $\log q = 2.37327$, and $\theta_1 = 7°\,10'$, we have

$$\theta_m = 4°\,8'.$$

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* If the rifling at the muzzle be of constant curvature for some portion of its length, the pressure N_1 corresponds to the point of the bore at which the parabolic rifling merges into the rifling of constant curvature.

As the distance of the origin of rifling from the base of the bore is 17.17 inches, the angle at this point becomes 3° 48′ greater than is now taken (2° 38′) in the 4.2-inch gun; for this angle

$$k = 0.002997, \text{ and } b = 12.08 \text{ ft.}$$

Substituting the latter quantities in equation (46), we obtain the pressures upon the rotating band of the projectile N for various points along the bore, as in the following table:

Distance of Section of Bore from Base of Bore.	Pressure upon Rotating Band of Projectile.
in.	tons.
29.0	7.22
33.6	7.56
42.0	7.65
53.2	7.48
61.8	7.36
85.4	7.19
115.5	7.17
127.4	7.19
136.0	7.23

It is evident from the above that for equal pressures on the rotating band in the extreme sections of the bore, the pressures in the intermediate sections change periodically in such a way that the maximum pressure (7.65 tons) is close to the value obtained for the muzzle sections.

For a charge of $5\frac{3}{4}$ lbs. Okhta smokeless powder especially prepared for the 4.2-inch gun (thickness of strip .0425 inch), we have

$$P_m = 1709 \text{ atm.}, \quad v_m = 845 \text{ ft. sec.},$$

$$P_1 = 467 \text{ atm.}, \quad V = 1962 \text{ ft. sec.},$$

$$\theta_1 = 7^\circ\, 10'; \quad U = 136 - 33.6 = 102.4 \text{ in.};$$

whence, from formula (47), we obtain

$$\theta_m = 4^\circ\, 44',$$

and for the angle of inclination of the rifling at the origin, 4° 20′.

The pressure upon the rotating band of the projectile at sections corresponding to the maximum bore pressure and the muzzle is

$$N_m = N_1 = 8.1 \text{ tons.}$$

In the case of initial angles determined by this method there would seem to be an advantage in parabolic rifling over rifling of constant curvature.

For charges of smokeless powder developing increased initial velocities, a greater initial angle of inclination is obtained than that taken in the 4.2-inch.

In the case of initial velocities exceeding 2000 feet with the use of charges of progressive powder developing moderate bore pressures, it may be stated that the calculated initial angle of inclination of the rifling is close to the final (at the muzzle) and that the pressures upon the rotating band approximate to those afforded by rifling of constant twist; *i. e.*, the superiority of parabolic rifling over rifling of constant twist does not become apparent.

§ V.

Empirical Monomial Formulæ for Breech Pressure, Initial Velocity and Force of Powder.

23. As applying to charges of saltpetre-sulphur-charcoal powders, Sarrau has determined empirical monomial formulæ for breech pressures and initial velocities. These expressions are of great value for solving questions in interior ballistics.

There does not yet exist a sufficient amount of experimental data to permit the final determination of suitable formulæ applicable to smokeless powders. On the basis of results obtained by us, employing various charges and projectiles and various densities of loading, we are able to present approximate expressions for breech pressures and initial velocities based upon data obtained from the kinds of powder experimented with.

The formula for initial velocity is

$$V = H\frac{\Delta^{\frac{1}{4}}\tilde{\omega}^{\frac{1}{2}}}{p^{\frac{5}{16}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

and the formula for breech pressure

$$P = K\Delta\tilde{\omega}p^{\frac{3}{4}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (49)$$

where Δ denotes the density of loading; *i. e.*, the ratio of the weight of the charge $\tilde{\omega}$ to the weight of water occupying a volume equal to that of the powder chamber.

Denoting the diameter of the powder chamber by D, and its length by l, we have

$$V = H'\,\frac{\tilde{\omega}^{\frac{3}{4}}}{D^{\frac{1}{2}}l^{\frac{1}{4}}p^{\frac{5}{16}}}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (50)$$

$$P = K'\,\frac{\tilde{\omega}^{2}p^{\frac{3}{4}}}{D^{2}l}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (51)$$

The relation between initial velocity and pressure for a given charge of smokeless powder, as determined by Longridge,* confirm our results.

In proof of the applicability of the above deduced formulæ, there are given in Table VI both experimental results and results calculated by use of the formulæ, arranged in parallel columns.

Results afforded by charge and projectile of maximum weight are employed as a basis for establishing comparisons.

Comparisons of calculated and experimentally determined values establish the fact that the proposed formulæ furnish results sufficiently accurate for practical uses.

24. Having determined for smokeless powders the characteristics H and K entering into formulæ (48) and (49), we may establish a simple relation between them and the coefficients (A) and (B) of equation (5), paragraph 18.

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* "Smokeless Powder and its Influence on Gun Construction." Translated by Captain Neelus, Artillery Journal, No. 2, 1891.

Assuming the maximum bore pressure P equal to the breech pressure, we obtain (formulæ (43))

$$\alpha = \frac{\alpha_1}{K}\,;\ \beta = \frac{\beta_1}{K}\,;$$

$$\alpha' = \frac{\alpha_1'}{H^2}\,;\ \beta' = \frac{\beta_1'}{H^2}\,,\ \text{and } \gamma = 1 + \nu - \gamma_1 \frac{K}{H^2}\,,$$

where

$$\alpha_1 = \frac{[\bar{1}.76956]}{\Delta\tilde{\omega}p^{\frac{3}{4}}x_m^{1.4}}\,;\ \beta_1 = \frac{[\bar{1}.46853]}{\Delta\tilde{\omega}p^{\frac{3}{4}}x_m^{2.4}}\,;$$

$$\alpha_1' = \frac{2g}{p^{\frac{3}{8}}\Delta^{\frac{1}{2}}\tilde{\omega}} \cdot \frac{1}{0.4}\left\{\frac{1}{x^{0.4}}\left(1 - [\bar{2}.83650]\,\frac{x^2{}_m}{x^2}\right)\right\}_X^{x_m} q \,.\, 2R\,,$$

$$\beta_1' = \frac{2g}{p^{\frac{3}{8}}\Delta^{\frac{1}{2}}\tilde{\omega}} \cdot \frac{1}{1.4}\left\{\frac{1}{x^{1.4}}\left(1 - [\bar{1}.61465]\,\frac{x_m}{x}\right)\right\}_X^{x_m} q \,.\, 2R\,,$$

and (formulæ (17) and (43))

$$\gamma_1 = 1.6732 \,.\, gq\Delta^{\frac{1}{2}}p^{\frac{3}{8}}u_m\,.$$

Whence (formula (45))

$$\left.\begin{aligned} A &= \frac{(1+\nu)\,\beta_1 H^2 - (\beta_1' + \gamma_1\beta_1)\,K}{\alpha_1'\beta_1 - \alpha_1\beta_1'} \\ B &= \frac{(\alpha_1' + \gamma_1\alpha_1)\,K - (1+\nu)\,\alpha_1 H^2}{\alpha_1'\beta_1 - \alpha_1\beta_1'} \end{aligned}\right\} \quad .\ .\ .\ . \quad (52)$$

25. The differential equation of the motion of the projectile in the gun, as stated by Sarrau, was given in paragraph 6.

$$(u + u_0)\,\frac{d^2u}{dt^2} + \theta\left(\frac{du}{dt}\right)^2 = f\,\frac{y}{M}\quad .\ .\ .\ .\ . \quad (53)$$

In the case arising when the charge is completely consumed in the bore of the gun, we may approximately determine the force of the powder f, by use of this last expression.

Denoting in (53) by y the weight of the products of combustion at the instant of time t, then, if the whole charge is consumed in the bore, we may substitute in the left hand member of the equation the value of the variables corresponding to the muzzle section of the bore; and in the right hand member $y = \tilde{\omega}$, where $\tilde{\omega}$ is the weight of the charge.

Multiplying both members of equation (53) by $M = \frac{p}{g}$, we find that

$$\frac{p}{g} \frac{d^2u}{dt^2} = P \cdot q,$$

where P is the pressure in atmospheres, and q the pressure of one atmosphere, expressed in units of weight, upon the base of the projectile and rifling.

Upon deducing (53) it was stated that $\frac{p}{2g}\left(\frac{du}{dt}\right)^2$ represented* the energy of the projectile in imparted accelerating and rotating impulses and the work of the powder gases expended in overcoming the friction of the rotating band of the projectile over the rifling and in overcoming other obstacles.

We may, therefore, present equation (53) in the following form,

$$(u + u_0) Pq + \theta(1 + \nu) \frac{pv^2}{g} = fy. \quad . \quad . \quad . \quad . \qquad (54)$$

Substituting in this last equation $u = U$, the length of the travel of the projectile in the bore, $v = V$, the initial velocity; $P = P_1$, the muzzle pressure, and $y = \tilde{\omega}$, the weight of the charge, we have

$$f = (U + u_0) \frac{P_1 q}{\tilde{\omega}} + \theta(1 + \nu) \frac{pV^2}{g\tilde{\omega}}. \quad . \quad . \quad . \quad . \qquad (55)$$

Assuming $\theta = 0.2$ for smokeless powder, we may employ the last equation for calculating the force of the powder f with data obtained from firings of varieties of smokeless powders experimented with.

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* The factor $\frac{1}{2}$ is included in the coefficient θ.

The results of these calculations are embodied in the following table:

Variety of Smokeless Powder.	Designation of gun in which powder was tried.	Weight of Projectile.	Weight of Charge.	Initial Velocity	Muzzle Pressure.	Force of Powder f.
		lbs.	lbs.	ft. sec.	atm.	atm. per sq. cm.
Okhta	Light gun	$16\frac{3}{4}$	$1\frac{65}{96}$	1673	329	10,700
Okhta	4.2 in.	$39\frac{3}{4}$	$4\frac{60}{96}$	1796	334	10,900
Okhta especially prepared for the 4.2-gun	4.2 in.	$39\frac{3}{4}$	$5\frac{72}{96}$	1962	467	11,500
Okhta prepared from naval gun cotton	4.2 in.	$39\frac{3}{4}$	$6\frac{45}{96}$	1960	539	11,000
French	4.2 in.	$39\frac{3}{4}$	$5\frac{33}{96}$	1845	380	10,400
Rottweil nitro-glycerine	4.2 in.	$39\frac{3}{4}$	$4\frac{15}{96}$	1846	396	12,800

It is evident from this table that the force, f, of gun-cotton powders is about 11,000 atmospheres per square centimeter, and of Rottweil nitro-glycerine powder about 13,000 per square centimeter.

Using formula (45) to calculate the force of coarse grained powder from data obtained from firings of the 4.2-inch gun, and putting $\theta = 0.6$ according to the results of Sarrau's investigations (p. 28, Nouvelles Recherches sur les Effets de la Poudre), we find

$$f = 2466 \text{ atm. per sq. cm.}$$

This result is close to that experimentally obtained by Noble for the varieties of saltpetre-sulphur-charcoal powders examined by him.

26. Having ascertained the force of the powder, f, we may find from formula (54) the weight of the products of combustion of the

charge for various sections along the bore, by substituting in it the values of P and v corresponding to these sections.

Dividing both members of the equation by $f\tilde{\omega}$, we obtain an expression for determining the portions of the charge consumed in various sections of the bore. We have

$$\frac{y}{\tilde{\omega}} = (u + u_0)\frac{Pq}{f\tilde{\omega}} + \theta(1 + \nu)\frac{pv^2}{g\tilde{\omega}f}. \quad . \quad . \quad . \quad (56)$$

Applying this formula to the calculation of $\frac{y}{\tilde{\omega}}$ from the results of firings of the 4 lbs. $3\frac{3}{4}$ oz. of Okhta smokeless powder with projectile of $39\frac{3}{4}$ lbs. weight from the 4.2-inch gun, we obtain the results contained in the following table :

Distance of Section of Bore from Base of Bore.	The Relation $\frac{y}{\tilde{\omega}}$.
in.	
16.9	0.
20.9	0.40
25.0	0.56
29.0	0.69
33.6	0.79
42.0	0.90
53.2	0.96
61.8	0.98
85.4	1.00
127.4	1.00
136.0	1.00

This table shows that when the maximum pressure has been developed in the bore, that is, when the projectile has traversed a distance of about three calibres, two-thirds of the charge has been consumed; and that after it has advanced eleven calibres, nearly the whole charge has been consumed.

TABLE I.*

Results of Firing the Light Gun (3.425-in. Cal.)

KIND OF POWDER.		Smokeless Okhta Factory.		Smokeless French.		Smokeless Schlüsselburg Factory.	
Weight of charge		1 lb. 11 oz. ($1\frac{65}{96}$ lbs.).		1 lb. 14 oz. ($1\frac{85}{96}$ lbs.).		2 lbs. 2 oz. ($2\frac{12}{96}$ lbs.).	
Thickness of strip or riband		.034 in.		.030 in.		.036 in.	
Initial velocity in ft.-sec.		1673		1686		1691	
		Exper'l.	Calc'd.	Exper'l.	Calc'd.	Exper'l.	Calc'd.
Pressure in atmospheres.	At base of bore	1530		1595		1409	
	Distance from base of bore. 4.5 in.	1474		1437		1315	
	12.0 in.	1490		1536		1340	
	19.0 in.	1588	1660	1595	1582	1391	1414
	24.5 in.	1489	1443	1353	1381	1371	1318
	34.5 in.	1063	940	940	889	1029	980
	48.0 in.	441	553	488	537	625	676
	66.5 in.	307	310	339	305	442	450
Calculated pressures determined by the equation $P=\frac{a}{x^{1.4}}\left(1+\frac{b}{x}-\frac{c}{x^2}\right)$.							
	log a	3.7971		3.8670		4.4868	
	log b	1.7804		1.6682		$\bar{1}.6959$	
	log c	2.4494		2.3444		1.2601	
x equals the distance from the base of bore plus 2.36 in., and expressed in calibres.							

Length of powder chamber, 9.35 in.; whole length of bore, 73.4 in.; weight of projectile, 16.75 lbs.

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*In all these tables the "registered" initial velocities and pressures represent mean values averaged from the results afforded by five shots. It may be noted that the differences between individual records were insignificant.

TABLE II.

RESULTS OF FIRING THE 4.2-IN. GUN.

KIND OF POWDER.		SMOKELESS OKHTA FACTORY.					
Thickness of strips or dimemsions of grain.		.035 inches.					
Weight of charge..................		4 lbs. 10 oz. ($4\frac{60}{96}$ lbs.).		4 lbs. $0\frac{2}{3}$ oz. ($4\frac{4}{96}$ lbs.).		3 lbs. $7\frac{1}{3}$ oz. ($3\frac{44}{96}$ lbs.).	
Weight of projectile		39.75 lbs.		39.75 lbs.		39.75 lbs.	
Initial velocity in ft. sec...........		1796		1657		1494	
		Exper'l.	Calc'd.	Exper'l.	Calc'd.	Exper'l.	Calc'd.
Pressures in atmospheres.	At base of bore....	1722		1390		1045	
	At distance from base of bore. 8.4 in.	1684		1348		1022	
	16.8 in.	1657		1349		1017	
	21.0 in.	1650		1321		1009	
	25.2 in.	1675		1325		1004	
	29.0 in.	1693	1742	1376		1025	
	33.6 in.	1658	1673	1391	1413	1050	1057
	42.0 in.	1490	1416	1280	1284	960	975
	53.2 in.	1154	1095	1011	1018	827	800
	61.8 in.	872	904	814	844	732	681
	85.4 in.	509	573	453	529	351	457
	127.4 in.	323	309	343	274	311	261
Calculated pressures determined by the equation $P=\frac{a}{x^{1.4}}\left(1+\frac{b}{x}-\frac{c}{x^2}\right)$, log a..................		4.4220		4.2392		4.4395	
log b..................		1.3235		1.6403		1.0208	
log c..................		2.1931		2.5232		2.0370	
x equals the distance from base of bore plus 6.68 inches, and expressed in calibres.							

Length of powder chamber, 16.9 in.; full length of bore, 136 in.

TABLE II—(CONTINUED).

RESULTS OF FIRING THE 4.2-IN. GUN.

SMOKELESS OKHTA FACTORY.						SMOKELESS MANUFACTURED AT THE OKHTA FACTORY FROM NAVAL GUN COTTON.		SMOKELESS FRENCH.		SMOKELESS KÖLN ROTTWEIL FACTORY.	
.035 inches.				.0425 in.		.044 in.		.032 in.		Cubical, edge of cube =0.14 in.	
4 lbs. 10 oz. ($4\frac{60}{96}$ lbs.)		4 lbs. 10 oz. ($4\frac{60}{96}$ lbs.)		$5\frac{3}{4}$ lbs.		6 lbs. $7\frac{1}{2}$ oz. ($6\frac{45}{96}$ lbs.)		5 lbs. $5\frac{1}{2}$ oz. ($5\frac{33}{96}$ lbs.)		4 lbs. $2\frac{1}{2}$ oz. ($4\frac{15}{96}$ lbs.	
35 lbs.		30.5 lbs.		39.75 lbs.		39.75 lbs.		39.75 lbs.		39.75 lbs.	
1862		1957		1962		1960		1845		1846	
Experimental.	Calculated.	Experimental.	Calculated.	Experimental.	Calculated.	Experimental.	Calculated	Experimental.	Calculated.	Experimental.	Calculated.
1536		1389		1794		1716		1731		1764	
1494		1354		1703		1642		1636		1670	
1490		1325		1685		1617		1607		1665	
1469		1310		1704		1608		1646		1685	
1461		1295		1675		1601		1692		1740	1759
1465		1303		1696		1622		1687	1727	1692	1690
1495	1536	1322	1377	1709	1709	1648	1635	1643	1679	1581	1589
1407	1401	1238	1243	1540	1598	1482	1544	1488	1436	1365	1344
1148	1119	1034	1022	1400	1349	1383	1346	1216	1140	1141	1065
999	933	944	871	1256	1176	1244	1199	968	960	893	903
524	593	530	546	743	829	837	888	591	637	551	614
313	315	318	336	Not Reg'd	504	Not Reg'd.	570	331	364	328	363
4.3629 1.5087 2.4089		4.5571 0.9844 2.0134		4.8196 $\bar{1}.9140$ 1.6378		4.9359 0.6637* 0.8228		4.6020 0.8998 1.8884		4.6604 0.2462 1.5207	

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* For this case the coefficient *b* became subtractive.

TABLE III.

RESULTS OF FIRING THE LIGHT GUN (3.42-IN.).

KIND OF POWDER.			COARSE GRAINED.	SMOKELESS POWDER.				
				Okhta.	Kazan.		Schlüsselburg.	Noble Nitro-glyc.
Thickness of strips or dimension of grain.			0.3 in.	.034 in.	.028 in.		.036 in.	Edge of cube =0.118″.
Weight of charge			$3\frac{40}{96}$ lbs.	$1\frac{40}{96}$ lbs.	$1\frac{70}{96}$ lbs.	$1\frac{45}{96}$ lbs.	$1\frac{78}{96}$ lbs.	$1\frac{72}{96}$ lbs.
Initial velocity in ft.-sec..........			1439	1463	1671	1474	1475	1752
Pressure in atmospheres.	At base of bore....		1563	990	1557	1057	986	1592
	At distance from base of bore.	4.5 in.	1389	941	1472	972	959	1422
		12.0 in.	1459	967	1490	978	941	1537
		19.0 in.	1258	980	1575	1058	992	1555
		24.5 in.	1077	962	1430	1016	906	1327
		34.5 in.	585	735	825	710	742	1065
		48.0 in.	<300	336	441	335	443	458
		66.5 in.	<300	319	323	325	370	373

Weight of projectile, 16.75 lbs.; length of powder chamber, 9.35 in.; full length of bore, 73.4 in.

TABLE IV.

RESULTS OF FIRING THE 4.2-IN. GUN.

KIND OF POWDER.			COARSE GRAIN'D	SMOKELESS POWDER.					
				Okhta.			Okhta made from naval gun-cotton.	French.	Rottweil.
Thickness of strips or dimensions of grain.			0.3 in.	.035 in.		.0425in.	.044 in.	.032in.	Cubical Edge of cube =0.14″
Weight of charge............			8 lbs.	$4\frac{47}{96}$ lbs.	$3\frac{82}{96}$ lbs.	$3\frac{90}{96}$ lbs.	$4\frac{51}{96}$ lbs.	4 lbs.	3 lbs.
Initial velocity in ft.-sec.			1455	1802	1681	1495	1488	1484	1485
Length of powder chamber, inches			16.9	14.9	12.4	16.9	16.9	16.9	16.9
Pressure in atmospheres.	At base of bore....		1730	1719	1529	890	895	1037	1061
	Distance from base of bore.	8.4 in.	1577	1680	1490	860	880	959	995
		16.8 in.	1644	1652	1476	846	859	947	995
		21.0 in.	1805	1659	1481	839	859	950	995
		25.2 in.	1366	1684	1487	864	861	964	1005
		29.0 in.	1338	1746	1543	867	863	953	1011
		33.6 in.	1101	1666	1430	877	862	941	955
		42.0 in.	767	1459	1276	833	831	843	853
		53.2 in.	603	1036	923	751	750	788	750
		61.8 in.	481	840	754	671	690	675	633
		85.4 in.	330	503	407	464	509	394	346
		127.4 in.	<300	Not recorded.	Not recorded.	Not recorded.	Not recorded.	306	<300

Weight of projectile, 39.75 lbs.; whole length of bore, 136 in.

TABLE V.

Rfsults of Firing 6-in. Gun.

KIND OF POWDER.		Prismatic, density 1.69	Smokeless Powder.					
			Okhta.			French.	Rottweil.	
Thickness of riband or dimensions of grain.		Height of prism 1 in.	0.053 in.			0.039 in.	Edge of cube 0.3 in.	
Weight of charge		21 lbs.	12 lbs.	10.4 lbs.	9 lbs.	$11\frac{1}{4}$ lbs.	$13\frac{3}{4}$ lbs.	$11\frac{1}{4}$ lbs.
Initial velocity in ft.-sec.		1525	1835	1635	1469	1783	1766	1502
Pressure in atmospheres.	At base of bore	1886	1750	1333	1011	1864	1592	1060
	Distance from base of bore. 10.4 in.	1788	1687	1317	963	1800	1557	1026
	23.7 in.	1808	1686	1295	967	1763	1549	1022
	26.0 in.	1742	1639	1306	969	1700	1529	952
	31.8 in.	1980	1649	1303	958	1876	1592	1006
	37.3 in.	1617	1734	1373	987	1850	1623	1056
	42.8 in.	1402	1798	1379	995	1885	1670	1193
	48.2 in.	1187	1693	1273	958	1714	1464	975
	79.6 in.	581	951	810	670	832	928	686
	110.0 in.	327	461	397	341	392	490	407

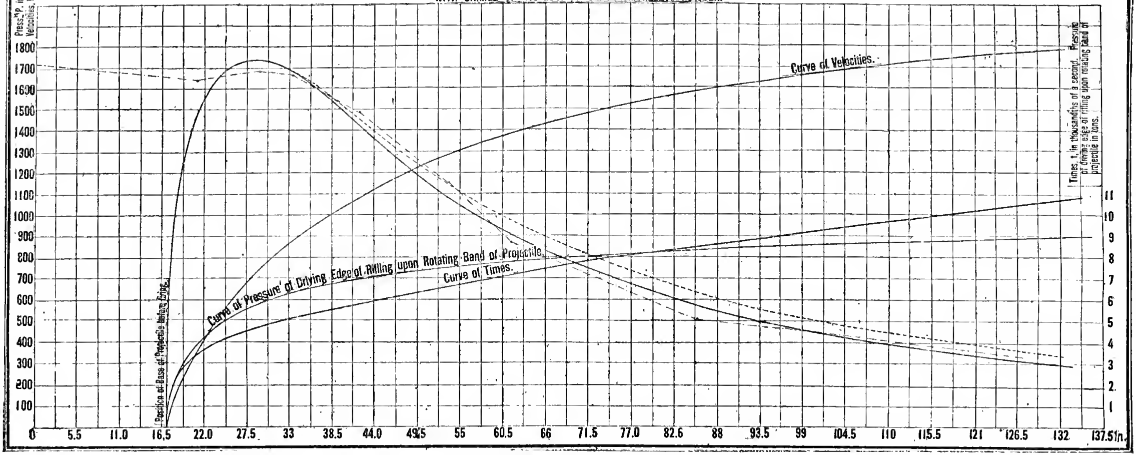
Weight of projectile, $81\frac{1}{4}$ lbs.; Length of powder chamber, 24.9 in.; whole length of bore, 114 in.

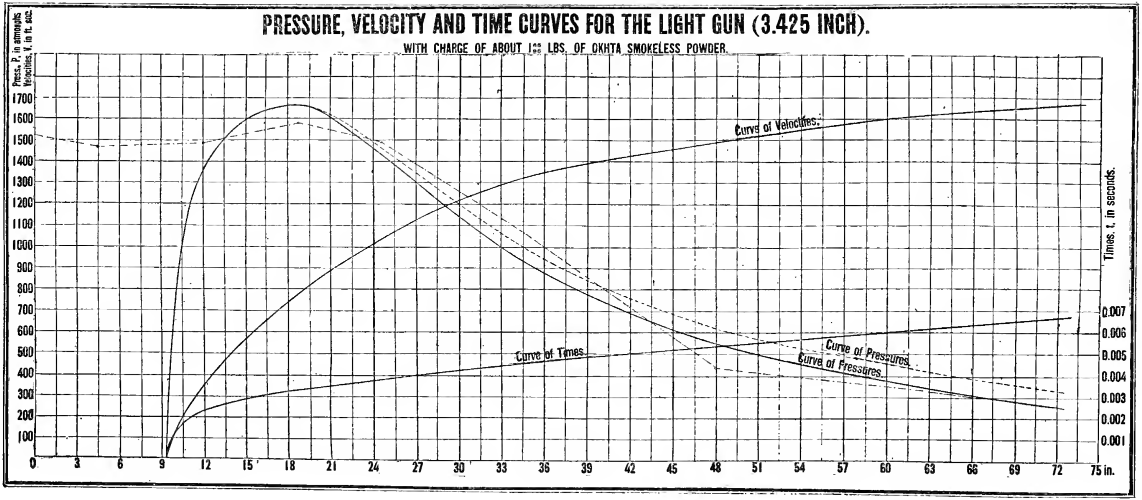
TABLE VI.

DESIGNATION OF GUN.	KIND OF SMOKELESS POWDER.	WEIGHT OF CHARGE.	WEIGHT OF PROJECTILE.	LENGTH OF POWDER CHAMBER.	BREECH PRESSURE.		INITIAL VELOCITY.	
					Registered.	Calculated.	Registered.	Calculated.
Showing relation of pressure and initial velocity to weight of charge.								
				In.	Atm.	Atm.	Ft.-sec.	Ft.-sec.
Light gun (3.42 in.)	Okhta . . .	$1\frac{65}{96}$ lbs.	$16\frac{3}{4}$ lbs.	9.35	1530		1675	
		$1\frac{40}{96}$ lbs.			990	1093	1463	1473
	Kazan. . . .	$1\frac{70}{96}$ lbs.			1557		1071	
		$1\frac{45}{96}$ lbs.			1057	1125	1474	1479
	Schlusselburg.	$2\frac{12}{96}$ lbs.			1409		1691	
		$1\frac{78}{96}$ lbs.			986	1027	1475	1502
4.2 inch gun.	Okhta, thickness of strips 0.035 in.	$4\frac{60}{96}$ lbs.	$39\frac{3}{4}$ lbs.	16.9	1722		1796	
		$4\frac{4}{96}$ lbs.			1390	1311	1657	1622
		$3\frac{44}{96}$ lbs.			1045	962	1494	1443
	Okhta, thickness of strips 0.0425 in.	$5\frac{3}{4}$ lbs.			1794		1962	
		$3\frac{90}{96}$ lbs.			890	842	1495	1478
	Okhta made from naval gun cotton.	$6\frac{45}{96}$ lbs.			1716		1960	
		$4\frac{51}{96}$ lbs.			895	841	1488	1501
	French.	$5\frac{33}{96}$ lbs.			1731		1845	
		4 lbs.			1037	972	1484	1486
	Rottweil.	$4\frac{15}{96}$ lbs.			1764		1846	
		3 lbs.			1061	917	1485	1444
6-in. gun of 190 poods (7600 lbs.) weight.	Okhta	12 lbs.	$81\frac{1}{4}$ lbs.	24.9	1750		1835	
		$10\frac{42}{96}$ lbs.			1333	1324	1635	1653
		9 lbs.			1011	984	1469	1479
	Rottweil.	$13\frac{3}{4}$ lbs.			1592		1766	
		$11\frac{1}{4}$ lbs.			1060	1067	1502	1520
Showing relation of pressure and initial velocity to weight of projectile.								
				In.	Atm.	Atm.	Ft.-sec.	Ft.-sec.
4.2 inch gun.	Okhta	$4\frac{60}{96}$ lbs.	$39\frac{3}{4}$ lbs.	16.9	1722		1796	
			35 lbs.		1536	1565	1862	1869
			$30\frac{1}{2}$ lbs.		1389	1396	1957	1960
Showing relation of pressure and initial velocity to length of powder chamber.								
				In.	Atm.	Atm.	Ft.-sec.	Ft.-sec.
4.2 inch gun.	Okhta	$4\frac{47}{96}$ lbs.	$39\frac{3}{4}$ lbs.	14.9	1719		1802	
		$3\frac{82}{96}$ lbs.		12.4	1529	1519	1681	1682

Curves of Pressures, Velocities, Times and Pressure of the Driving Edge of the Rifling upon the Rotating Band of the Projectile for the 4.2-Inch Gun.

WITH CHARGE OF $4\frac{00}{88}$ LBS. OF OKHTA SMOKELESS POWDER.



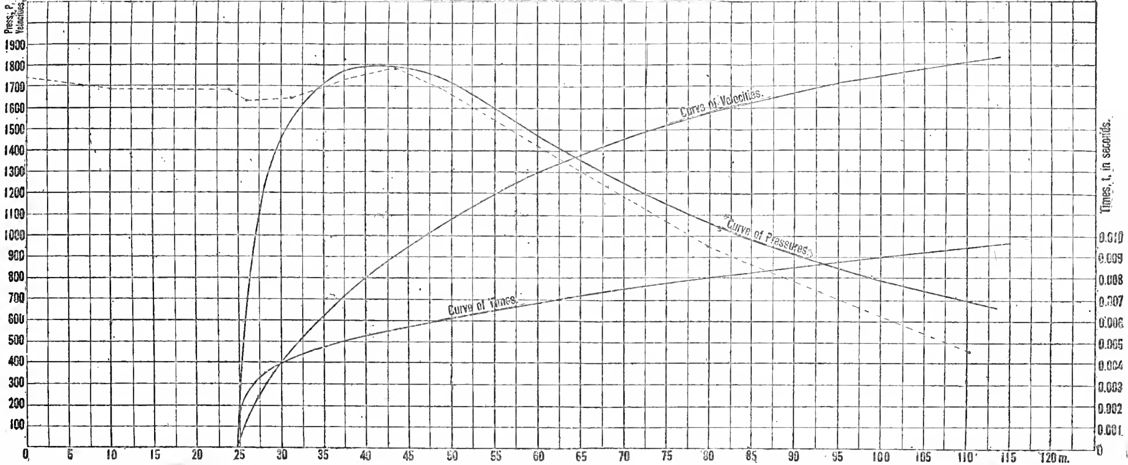


PRESSURE, VELOCITY AND TIME CURVES FOR THE LIGHT GUN (3.425 INCH).

WITH CHARGE OF ABOUT $1\frac{65}{96}$ LBS. OF OKHTA SMOKELESS POWDER.

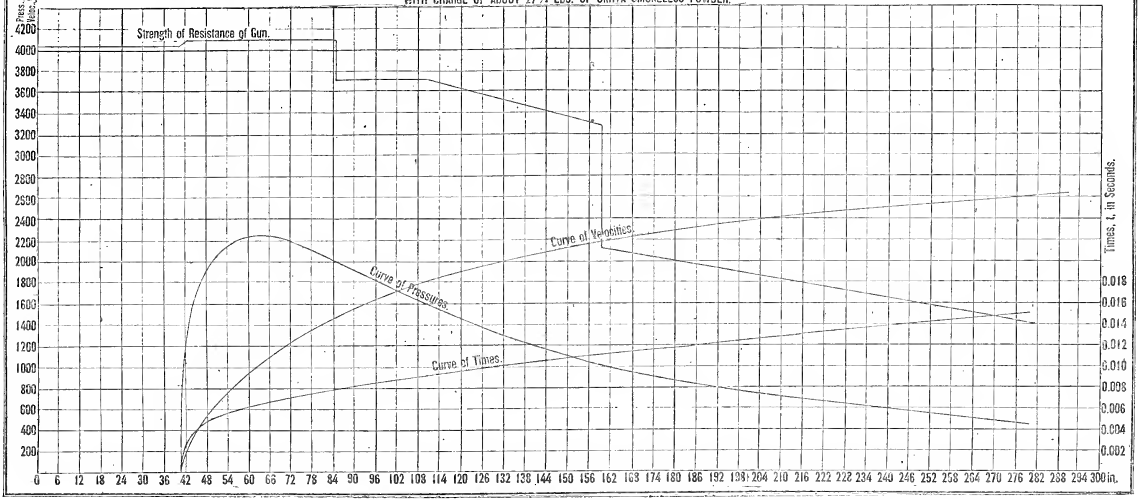
PRESSURE, VELOCITY AND TIME CURVES FOR THE 6-INCH GUN OF 190 POODS (7600 LBS.) WEIGHT.

WITH CHARGE OF ABOUT 12 LBS. OF OKHTA SMOKELESS POWDER.



PRESSURE, VELOCITY AND TIME CURVES FOR THE 6-INCH CANET GUN OF 50 CALIBRES LENGTH.

WITH CHARGE OF ABOUT 27 ½ LBS. OF OKHTA SMOKELESS POWDER.



U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE DISAPPEARING GUN AFLOAT.

By Assistant Naval Constructor Richmond Pearson Hobson, U. S. N.

The following paper is the substance of a report made last April on a Model with Disappearing Turrets submitted to the Navy Department by G. W. Van Hoose, Esq.

The idea of the possibility of interest in the publication of the report was first suggested by the bearing that the portion treating of the relative protection of the different elements of efficiency has on the method of estimating naval strength, of estimating the power or value of a vessel of war, as found in the author's paper on the Study of Coming War and in the discussion of the method.

The idea was further suggested by the interest evinced by officers in the subject of the relative exposure of the parts of a vessel, the probability of a particular part being hit in action by the projectiles of different calibers, and the effects of such hits on the efficiency of the vessel.

Some ideas found to be held currently are somewhat at variance with the conclusions arrived at, and some are unformulated, evidently from lack of data, and it was decided that these points, which are of such vital interest both for design, particularly in the distribution of armor, and for directing an engagement, should be further investigated and expanded into a paper which would omit the parts of the report of minor interest. But the pressure of current duties has prevented this investigation and offers little prospect for the near future.

In consequence, it has been decided to offer the paper for publication as it stands. Having been made thus only as incident to, or involved in the investigation of a particular case, the treatment of the broad subject alluded to, while comprehensive in scope, is only suggestive, not exhaustive in its nature.

I.

The model was presented by Mr. Van Hoose in person without any written statement, explanation, or description whatsoever, with the verbal request to the effect that the dispositions embodied and the principles and ideas illustrated be examined as to their utility for adoption on vessels of war.

In order to approximate to the nature of the request and to the extent of the claims, questions were put to and answered by the applicant as to the features, strategical and tactical, of the vessel represented by the model.

These questions and answers are given below. The answers and the explanation of the model demonstrated the fact that the pervading idea is the use of the disappearing principle in such a form that, combined with a flush upper deck, it will permit fire across the above deck positions when the guns are below deck, thus reducing the obstruction and increasing the effective angles of fire.

The method employed by the applicant to realize the ideas of the system is indicated only in outline on the model and was supplemented later by a sketch from patent specifications showing a modified form of barbette and a sectional elevation without dimensions, scantlings, details, or description of any kind. In his verbal description of the method, the applicant explained only the ideas adopted and expressed the desire that the details as found be not entered as part of the examination, as their purpose was only that of illustration. In consequence, a critical examination of the details of the method is not entered into at length, though it is shown that on the practical efficiency of the method and the perfections of the details will depend the entire value of the system.

In order to arrive at conclusions as to the utility of the disappearing principle in the form in which it appears, the features are examined as follows, namely :—

1. The sacrifice of the superstructure, entailed by the system.
2. The extent of the advantage gained in increase of power of the main battery and in increase of protection to guns.

In investigating the increase of protection to guns the question of the advantage to be gained by *any* increase is first considered, the method adopted being the investigation in usual systems of the relative protection of turret guns and of the other elements of efficiency, adequate protection to each element being the object sought. Then the amount of the increase realized by the system proposed over usual systems is considered.

3. Remarks on certain features inherent in the system and on certain features of the methods proposed by the applicant.

4. A summary comparison of the system in an ameliorated form with systems employed abroad on board ship.

5. Summations, conclusions.

II.

INTERROGATORIES.

GENERAL STRATEGICAL AND TACTICAL FEATURES.

Q. Speed?

A. Not specified.

Q. Endurance at a given speed?

A. Not specified.

Q. Type of vessel?

A. Seagoing battleship.

Q. Designed for engaging in squadron or in duel?

A. For both; duel preferred.

Q. Main object?

A. To crush enemy by battery power.

Q. Best position for engaging—end on, on quarter, or abeam?

A. Any position; end on preferred.

Q. Best distance for engaging—long range, moderate range, or close quarters?

A. All three; moderate range preferred.

SUMMARY DESCRIPTION.

Q. Principal dimensions?

A. Not specified.

Q. Displacement?

A. Not specified; supposed to be not less than 12,000 tons.

Q. Condition of stability and steadiness of gun platform?

A. Not specified.

Q. Apportionment of weight?

A. Not specified.

OFFENSIVE POWER.

1. *Artillery.*

Q. Heavy artillery?

A. Four 10″ B. L. R. or larger caliber, in two armored cages, disappearing after firing to loading positions within two barbettes situated in center line of vessel, one forward and one aft.

Eight 8″ B. L. R. or larger calibre, in four armored cages, disappearing after firing to loading positions within four barbettes situated two on each beam in waist.

Q. Medium caliber artillery?

A. Not specified; preferred to be developed as much as possible. The pieces—8 on the gun deck, 4 on bridge deck, 1 on each side of the cages of the heavy guns in center line and 1 between the two guns of each waist barbette—are all of undefined caliber.

Q. Light artillery?

A. Not specified other than four Gatling guns in two military tops of two masts that are raised and lowered, the top being housed below the upper deck and the guns firing from a position above the upper deck as well as in the raised position.

Q. *Angle of fire.*—For successive fire?

A. All heavy guns have an arc of practically 360 degrees.

Q. For volley fire?

A. In two volleys of short interval of separation all guns can bear in all directions. End on, the first volley brings to bear two 10″ and four 8″; the second volley the same; quartering fire, one volley brings whole battery; beam fire, the first volley brings to bear four 10″ and four 8″, the second volley brings to bear four 8″.

Q. Ammunition supply?

A. Nothing specified.

2. *Torpedoes.*

Q. Number of submarine discharging tubes?

A. Not specified.

Q. Number of over-water discharging tubes?

A. Not specified.

3. *Ram.*

Q. Ram bow?

A. Affirmative. Nothing further specified.

DEFENSIVE POWER.

Protection by Armor.

Q. For hull and stability by side armor?

A. Nothing specified.

Q. For hull and stability by deck armor?

A. Nothing specified, although it would have an armored bulkhead forward of forward barbette.

Q. For artillery and personnel?

A. For heavy guns, armored cages with heavy armor on their sloping faces and lighter armor on the sides, disappearing for the loading position, guns and cages, into fixed barbettes of heavy armor. Nothing further specified.

Q. Protection by subdivision?

A. Nothing specified.

Q. Protection by coal?

A. Nothing specified.

Q. Protection by empty spaces?

A. Nothing specified.

Q. Protection by nets?

A. Nothing specified.

STRUCTURAL FEATURES.

Construction.

Q. Form of lines?

A. Nothing specified.

Hull.

Q. Internal arrangements, position of boilers, engines, coal bunkers, ammunition rooms, quarters, berthing, etc., etc.?

A. Nothing specified.

Q. Upper works?

A. There are to be no upper works, other than a bridge and boat cradles built on three or more skid beams.

Q. Ventilation, drainage, lighting, etc., etc.?

A. Nothing specified.

Hull Fittings.

Q. Rudder, steering gear, anchor gear, boat gear, torpedo net gear, etc., etc.?

A. Nothing specified.

Q. Masts?

A. Two or more military masts to be raised from housed positions below the upper deck to fighting positions by appliances, using any sort of power, and to be secured in the fighting positions by stays and guys. Nothing further specified.

Propulsion.

Q. Indicated horse power?

A. Not specified.

Engines.

Q. Number, type, disposition, distinctive features, etc., etc.?

A. Nothing specified.

Boilers.

Q. Number, type, disposition, distinctive features, etc., etc.?

A. Nothing specified.

Screws.

Q. Number, type, disposition, distinctive features, etc., etc.?

A. Nothing specified. The model has three four-bladed screws.

Summing up the answers, the applicant intends the model to represent a seagoing battleship of large displacement. The battery of heavy guns is to be highly developed, their effective power is to be increased by increasing largely the arc of fire, to which end all upper works are sacrificed, and the guns are made to be able to disappear within barbettes below the upper deck after firing so as to leave the field unobstructed for other guns. The military masts are also made to disappear below the upper deck. In this manner, by firing in turn, each gun can be brought to bear over the whole horizon, and the barbettes are so grouped that, for certain points on the bows and quarters, all guns can be brought to bear simultaneously.

While increasing the arc of fire of other guns by disappearing below the upper deck, the heavy guns are intended to increase their own protection by lowering into barbettes, reducing the time of exposure to direct fire to the interval necessary for training and sighting and during this interval protection of the breech against rapid-fire guns is afforded by cage armor, with the increased thickness of armor on the front sloping face.

The general disposition by which these objects are represented to be accomplished is shown in sketches of the model Figs. 1, 2, 3. The ratio of beam to length is 5 to 1; the ratio of beam to draught 2.8 to 1, the ratio of freeboard to draught 1 to 1.485. The same ratios for the Iowa are 5 to 1, 3 to 1, and 1 to 1.354, respectively. The proportions are good; and as a piece of workmanship the model shows a skill and ingenuity remarkable under the circumstances under which it was made.

The features which render the carrying out of the model as it stands impracticable if not impossible—such as the disposition of rapid-fire guns along with heavy guns—will not be discussed, as it is evident from the answers above, the applicant's object in making and submitting the model was not to offer a model for a design, but to offer simply an illustration, in concrete form, of a method of increasing the effective power and efficiency of the main battery, by increasing the angle of fire and the mean security of the heavy guns.

To this end, two distinct dispositions are employed: First, the disposition of a flush upper deck without any superstructure or upper works of any consequence that would obstruct the angle of fire; second, the use of disappearing mounts, by which the heavy guns, after firing, can be made to sink into armored barbettes below the level of the upper deck, leaving the field unobstructed for the fire of other guns and realizing an additional security during the period of loading.

Upper works have been sacrificed to arcs of fire in degrees varying from the least to the greatest in war vessels of nearly every maritime power, while disappearing guns have been mounted in five vessels, four Russian and one British. Sketches Figs. 4 and 5 show the disposition on the three recent Russian battleships, the Catharine the Second, the Tchesme, and the Sinope, launched in 1886 and 1887. Fig. 6 shows the disposition on the Russian circular coast-defence vessel, the Vice Admiral Popoff, launched in 1875. Figs. 7 and 8 show the disposition on the British battleship, the Temeraire, completed in 1877. On the Catharine the Second class, the six 12″ guns are mounted in a single armored redoubt. On the Temeraire the two barbettes are situated at the extremities with upper works intervening, not shown on the profile sketch but indicated on the plan, which allows the disappearing gun to realize only the moderate angle of fire of 240°. On the Vice Admiral Popoff the two disappearing guns are mounted side by side in one position. In each case the guns are raised only high enough to clear the top of the encircling armor. In none of the cases is the disposition made for firing the heavy guns over the barbettes, redoubt, or pit, into which the guns sink. The only objects sought in adopting the disappearing principle are the increase of protection and the saving of weight.

The model represents, as far as extensive research has disclosed, the first disposition where the disappearing principle is designed to clear the field of guns during the process of loading in such a way as to permit unobstructed fire across the space occupied by them in the firing position, the deck being cleared of other obstructions, to realize thus the double purpose of increasing the effective angles of fire of the heavy guns, and, at the same time, of increasing their protection.

III.

In order to realize the advantage of this novel feature, it is first necessary to clear the deck of obstructions. The superstructure must be abandoned with the mounts it furnishes within and on top for pieces of the secondary battery and housed space available for quarters, berthing, etc. Incident to this measure there would be a gain of weight and an increase of stability, depending in amount on the weight and position of the objects removed. It would further reduce the area of the target offered by an amount depending on the dimensions of the superstructure.

On the other hand, it would *increase* the period of roll and consequent steadiness of gun platform by an amount depending on the weight and position of the objects removed. It would reduce the secondary battery by an amount depending on the number and importance of the pieces whose mounts were swept away. In many cases, the loss of power of secondary battery would be so great as to be altogether inadmissible, not only because of the heavy reduction in power of offense against unarmored and lightly armored vessels and parts of armored vessels, but also because of the serious reduction of power of defense against the attack of torpedoes, now so widely carried by unprotected but swift vessels.

MODEL SUBMITTED BY G. W. VANHOOSE, ESQ.

FIG. 1 OUTBOARD PROFILE,
TURRETS AND MASTS IN FIRING POSITION.

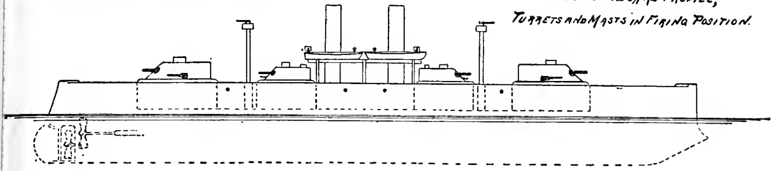
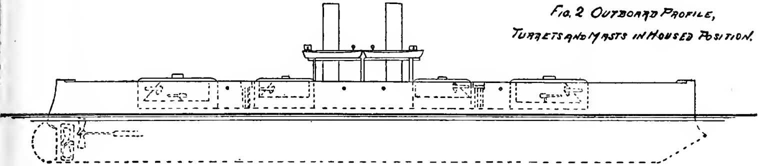


FIG. 2 OUTBOARD PROFILE,
TURRETS AND MASTS IN HOUSED POSITION.



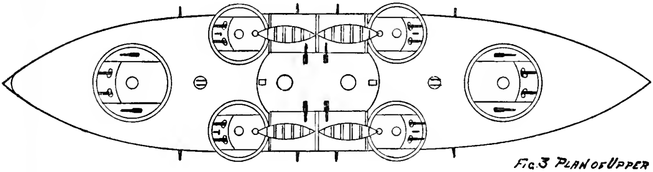


FIG. 3 PLAN OF UPPER DECK

CATHERINE II

FIG 4

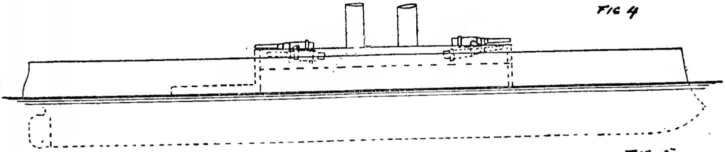
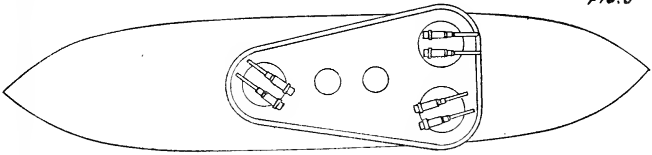


FIG. 5



TEMERAIRE.

FIG 7

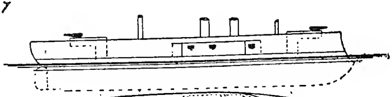
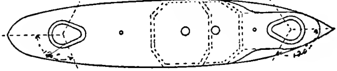


FIG. 8



In the case of the Indiana, the loss would comprise all four of the 6″, and fourteen out of eighteen of the 6-pdrs., practically an annihilation of the secondary battery, which would reduce the rôle of the battleship to that of a coast-defense vessel unfitted to approach within radius of a hostile torpedo flotilla.

The secondary battery, being indispensable and being swept from the level of the heavy guns, must find mounts below this level, or else above it on objects not swept away, which can carry mounts for only light calibers. This would lead naturally to a developed gun deck battery which would necessitate a deck more of freeboard, increasing thereby the hull weight and the size of target offered and necessitating higher barbettes which must extend from the upper deck to the armor deck, increasing thus the weight of armor. The result would either be a serious decrease of weight and consequent reduction of efficiency of other important elements, or else a considerable increase in displacement with consequent increase of cost. It would change the Indiana into an Iowa with her upper deck extended to the stern, permitting an increase of power of secondary battery and necessitating an increase of her displacement and cost.

There might be a condition in which the necessity of a gun deck and the incident advantages just cited could be avoided. The guns of the secondary battery, instead of being lowered to the distance of the gun deck, could be left still to fire over the upper deck, if they were within light turrets similar to those adopted on recent French battleships, the platforms of the turrets being below the level of the deck and the gun a short distance above this level. The rise of the heavy guns above the deck would have to be somewhat increased so that they could fire over these turrets without danger of injuring them from the blasts, measures being taken to prevent depression when firing in the line of the small turrets sufficient to hit them. Guns of lighter caliber swept away could be mounted higher on the bridge, which could be supported in a developed form with chart-house by smokestacks and masts. The boats whose cradles would be swept away with superstructure, could be carried on skid beams assembled and secured by bolts which, before action, would be unrigged and sent below, the boats being put overboard. The conning-tower would have to remain the sole obstruction, offering a conspicuous and exposed

VICE ADMIRAL POPOFF

FIG. 6

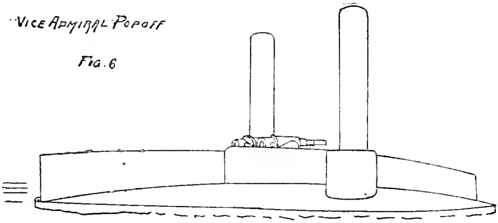
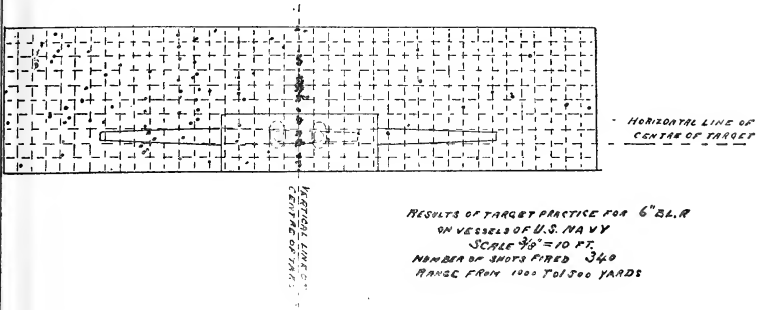


FIG. 4.



RESULTS OF TARGET PRACTICE FOR 6" B.L.R
ON VESSELS OF U.S. NAVY
SCALE 3/8" = 10 FT.
NUMBER OF SHOTS FIRED 340
RANGE FROM 1000 TO 1500 YARDS

FIG 11.

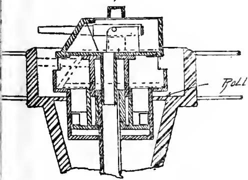


FIG 13

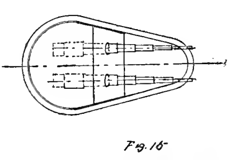


FIG 12.

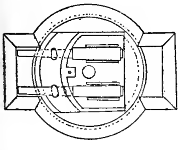


FIG. 15

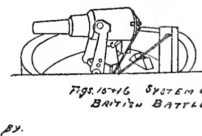
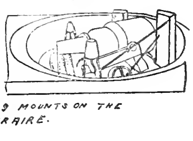


FIG 16.



FIGS. 15 & 16 SYSTEM OF DISAPPEARING MOUNTS ON THE BRITISH BATTLE-SHIP TEMERAIRE.

FIGS 11 AND 12.
SYSTEM OF DISAPPEARING MOUNT PROPOSED BY
G.W. VAN HOOSE ESQ
FIG 13
FORM OF BARBETTE SUGGESTED FOR
DISAPPEARING MOUNT

target, or else it would have to descend to the level of the small turrets just described, with the necessity of having a portion of the horizon cut off by the heavy guns while in the firing position. With the conning-tower placed well forward of the forward turret, with perhaps a second one aft, abaft the after turret, this disposition would incur but slight objection on this score, offering a better view than the usual disposition within the horizon of an engagement, a view obstructed only in the rear and then only intermittently by the heavy guns. A conning-tower consistent with this condition would be one that could rise and fall like the turrets; or, if not the conning-tower proper, an armored tube large enough to contain one or more men with an apparatus for communicating to the conning-tower proper.

Thus, for battleships, the disadvantages incident to the sacrifice of the superstructure and the removal of the objects of obstruction above the upper deck in order to have the deck flush and clear for the disappearing guns, though serious, are not, on the whole, without the possibility of partial remedy. In many cases they are not of serious consequence. This first measure, necessary to the realization of the advantages sought in increasing the effective angle of fire of the heavy guns, does not present insuperable obstacles.

For coast defense vessels, which have less need of a developed secondary battery, the disadvantages and difficulties are less serious than for battleships.

IV.

With a flush unobstructed deck, the minimum total angle of fire gained for each gun by the disappearing system proposed is the sum of the angles subtended by the turrets of other guns. As a matter of fact, a shot would never be allowed to be fired so that the circumference would pass tangent to a turret.

The absolute minimum of a gain would be the sum of the angles subtended by the turrets plus the angles subtended in each case by the caliber of the gun firing placed at a distance equal to the distance of the point of tangency from the gun.

Where the guns of the two turrets are on the same level it would not be safe to allow the projectiles to pass within the circle swept by the muzzles of the guns of the turrets in question. Assuming

Fig. 14.

SYSTEM OF DISAPPEARING MOUNT ON THE RUSSIAN BATTLE-SHIP CATHARINE II T'CHESME' AND SINOPE

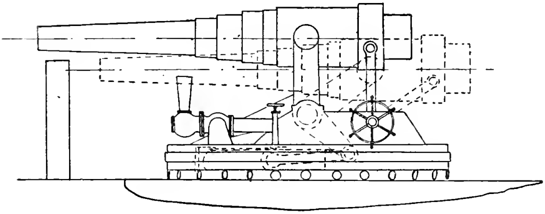


Fig 17

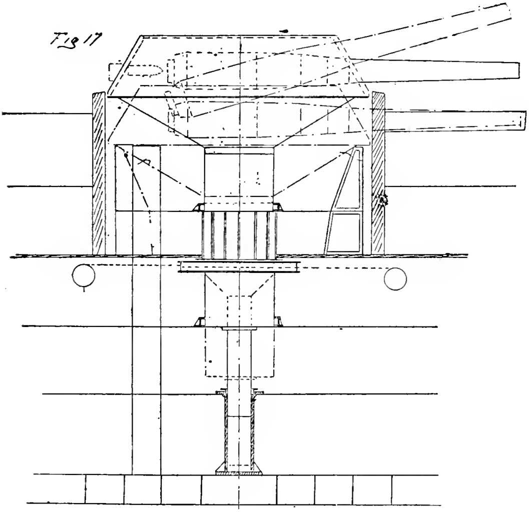
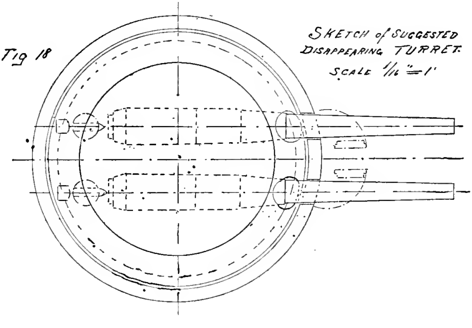


Fig 18



SKETCH of SUGGESTED DISAPPEARING TURRET.

SCALE 1/16" = 1'

that the gain is only the sum of the angles subtended by the turrets in the case of guns on different levels, the least favorable assumption, and that it is the sum of the angles subtended by the circles swept by the muzzles when the guns are on the same level, the total gain in usual cases would be large even with the best disposition of the turrets. On the Iowa, the sum of the angles subtended by turrets for the guns of a 12″ turret is about 35 degrees; the dead angle as now provided being about 90 degrees. The sum for the guns of an 8″ turret is about 95 degrees, the dead angle being 195 degrees. When the circles swept by the muzzles are taken instead of the turrets for the cases of guns on the same level, the sum becomes 90 degrees, the total dead angle, for the forward 12″ guns, and 165 degrees, $\frac{32}{39}$ of the dead angle, for all of the 8″ guns, the forward 12″ and all of the 8″ guns being on the same level, which indicates that in reality the presence of a superstructure would add but little to the dead angle.

The necessary gain in angle of fire for the Iowa, with her present position of guns, by the use of mounts disappearing as proposed, would thus be as follows :—

For the forward	12″ guns,	- - - -	90	degrees
" " after	12″ "	- - - -	55	"
Total for	12″ "	- - - -	145	degrees
Mean gain		- - - -	72½	"
For all the	8″ "	- - - -	165	"

The effective gain would practically be in each case the dead angles, 90 degrees for the 12″ guns and 195 degrees for the 8″ guns. Assuming that the angles gained are of equal value with angles of the other bearings, that angle of fire is of uniform importance around the horizon, an assumption that will not be discussed, being of sufficient accuracy for the purpose of the present comparison, the proposed system would add practically ⅓ to the effective angle of the 12″ guns and practically double the angle of the 8″ guns. Take muzzle energy as the comparison between the two calibers. The four 12″ guns in a single round aggregate 4 × 26,000 ft. tons, equals 104,000 ft. tons, and the eight 8″ guns in a single round aggregate about 8 × 8000 ft. tons, equals 64,000 ft. tons. The relative amount of energy in a single discharge is as 13 to 8. Taking one minute and a half as the interval between the rounds for the 8″, and 3 minutes as the interval for 12″ guns, then, in a given length of time, sufficiently long, the total muzzle energy generated by the two batteries would be in the proportion of $\frac{13}{8} \times \frac{1}{2}$, or 13 for the 12″ battery and 16 for the 8″ battery. This is the relation of the *quantities* of offensive energy generated. To make the comparison more complete, a factor representing the relative *qualities* of the two energies should be introduced. This factor would vary in each engagement with the nature of the target, depending upon its relative vulnerability to hostile energy in the form of 12″ projectiles and 8″ projectiles in movement. It will be sufficiently accurate for the present purpose to assume that the average target with which the vessel is designed to engage is equally vulnerable to the two kinds of energies, that the quality of unit quantity of energy is the same for both batteries. The weights to be given to the two batteries become then 13 and 16 for the 12″ and 8″ respectively, and the increase in the total effective angle of the two batteries combined, due to the system proposed, would be the following:

Increase due to an increase of
$\frac{1}{3}$ in the 12″ battery .... $\frac{1}{3} \times \frac{13}{29} = \frac{13}{87} = .149$
Increase due to doubling the angle
of the 8″ battery .... $\frac{16}{29} = .552$
Total increase........................... $\frac{61}{87}$ .701

The total effective angles of fire of the heavy guns in the two cases are thus in the proportion of 1 to 1.7. Suppose T equals $\frac{61}{87}$ the mean interval of time necessary to generate unity quantity of muzzle energy for the guns mounted on the Iowa, and suppose T' the same interval for the guns mounted on the system proposed, then the relative total effective power of the two systems would be in the proportion of 1 to $1.7 \times \frac{T}{T'}$. The value of T is easily found, knowing the rapidity of fire of 8″ and 12″ guns. The value of T' will depend on the efficiency of the mounts in reducing the interval required in lowering and lifting, and in training to and from the loading position. T' may be expressed as equal to $T + t$, where t represents the time required in performing the additional operations incident to the system, and the relative power would be as $1.7 \times T$ to $T + t$.

Represent $\frac{T}{t}$ by e, the efficiency of the mount; then the relative power is $\frac{1.7}{1+\frac{1}{e}}$.

This equation shows how the advantage in gain would be easily dissipated by slowly acting mechanism, particularly as the caliber becomes smaller when the value of T, the time between shots, is small and the value of t is relatively larger. It would be useless, other things being equal, to have two guns available against a target instead of one if they fired only half as rapidly. The value of t will comprise t_1, the time to revolve from the bearing of fire to the disappearing position, t_2 the time occupied in descent, t_3, the time occupied in rising, and t_1 again, the time required to revolve back to the bearing of fire. Assume, for simplicity, that the conditions are those for heavy turrets. Taking the mean angle of rotation as 90°, the time t_1 required would be about 5 seconds with efficient training mechanism. Allowing 3 seconds for descent t_2, and 15 seconds for ascent t_3, the value of t becomes 28 seconds, say ½ minute. Taking T as 3 minutes, T' becomes 3½ minutes and $\frac{T}{T'}=\frac{3}{3\frac{1}{2}}=\frac{6}{7}$. The ratio would be smaller, as stated above, for smaller turrets. The relative offensive power of the two systems becomes $1.7 \times \frac{6}{7}$ equals 1.45. The loss in rapidity of fire would be greater with imperfect mechanism.

Thus, in sum, the gain in power of battery, which at first sight appears so great on account of the large increase in angle of fire, will depend on the success with which the mechanical difficulties are surmounted, on the efficiency of the mechanism for effecting the operations incident and necessary to the system.

V.

Increase in protection and not increase in angle of fire was the object that gave birth to the disappearing mount. The birth took place on shore about a century ago and was produced by the increase in accuracy of fire which necessitated improvement in the methods of gun protection, for the guns, being the main elements in the infliction of injury, the immediate object of battle, and being mounted usually in commanding positions, form the most important target for the concentration of hostile fire. These improvements took the form of minimum embrasures and disappearing mounts. On a disappearing mount, the gun is in view of the enemy only in the firing position. After firing, it disappears into a position more or less secure, where it remains during the process of loading and now usually during the process of pointing, the object sought and partially realized being the reduction to a minimum of the time of direct exposure. The security of the housed position is realized by the use of earth, masonry or armor, or a combination of these means, with or without the additional security of invisibility. The security is practically perfect where the gun disappears behind or under unbroken covering that gives no indication of the spot. Where such conditions can be realized, the advantage of the disposition is overwhelming; the enemy has no target, he may not have the range, and he cannot accurately keep the bearing. A few years ago, a dummy 10″ gun was mounted on a disappearing carriage off the coast of England and was made to rise and fall at regular intervals giving out a puff of smoke like a gun in action, while it was fired on by all the battery that the battleship Sultan could bring to bear and it was found that absolutely no effect could be produced, though the conditions were most favorable for the attack.

Thus ashore the disappearing principle has decided military advantages, and the inherent practical difficulties of the mount are not of great importance. In many cases, like the one just cited, in particular those of batteries covering sea approaches, where the guns can be scattered and where no objects would indicate the positions of the gun pits, where the enemy as a rule, will lack guns adapted to oblique fire, the only fire to which pits are seriously exposed, even in the case of the enemy possessing accurate knowledge of the range and bearing, in these cases, the advantage of the disappearing principle is so pronounced as to insure practically a perfect defense, without the expense of armor, having a sea-borne enemy at a hopeless disadvantage, exposed to injury and powerless to inflict it in return. When, however, the position remains visible, forming a permanent target, the conditions change, and the methods of defense common to other mounts, earth, masonry and armor, must be resorted to.

When the position is vulnerable and its welfare is essential to the gun, conditions can be imagined where it might be more advantageous for the gun offering a small target to remain in sight and invite fire, much of which would pass over, which, if aimed at the position, would strike it. The value of a vessel of war, as measured by her power to inflict injury, depends on the power of her weapons and on her power or ability to use them. Moreover, it results from a product of these two interdependent elements, which is greatest when both elements are large together. It would be needless to have powerful weapons, if use could not be made of them. The power to use the guns of a vessel in action will depend on the power to maintain alike their own integrity and the integrity of the platform that carries them ; will depend alike on the protection afforded to guns and their crews, and the protection afforded the hull. It would be useless to have well protected guns if the vessel sank or turned over, or changed trim, or heeled to such an extent as to render their use impossible. It would be unwise to overprotect the guns and underprotect the hull, or *vice versa.*

With turret guns as usually mounted on battleships, the breech, including about ½ the length, is protected by heavy armor. When pointing at right angles to the angle of fire, the breech may be said, in the comparative sense adopted, to be perfectly protected. When pointing in the direction of the line of fire it is exposed to projectiles that may enter the gun ports and explode.

If the breech plug were closed at the time of explosion, the breech proper being cylindrical in form and fitted and held to the platform by straps, not trunnions, could stand heavy impact from fragments of projectiles without being seriously injured. If the breech were open and a shot or fragment struck the breech plug it would be disabled without doubt. On the whole, the breech of the gun is but slightly vulnerable. At the Yalu, a fragment, entering under the hood and deflected downward, killed the whole crew, but did not affect the guns.

The chase of the gun is exposed in the open, including about one-half of the total length. A shot from a gun of ½ the calibre, striking normally, would probably disable the gun, but the form is cylindrical, and when struck in a line deviating from the radius of a section, offers an oblique surface of large resistance, the obliquity increasing rapidly as the direction of the impact varies from the radius. Further, a considerable indenture could be cut in the wall of a gun without disabling it, the strain in a longitudinal direction on a cross section being small.

Guns being now mounted in beds and strapped to the platforms, not as formerly on trunnions, a shot would strike the chase with considerable force and leverage without springing the securings of the gun. On the whole, the chase of the gun, though more vulnerable than the breech, could receive large punishment without disabling the gun.

In the Yalu the chase of a gun of moderate caliber was struck near the muzzle by a projectile from the secondary battery without disabling the gun or interfering with its fire.

Figure No. 9 represents the results of target practice with the 6″ guns in the U. S. Navy at ranges from 1000 to 1500 yards on the following vessels: Atlanta, Baltimore, Bennington, Boston, Charleston, Chicago, Concord, Newark, Petrel, San Francisco and Yorktown. The total number of shots fired was 340.

If a gunport of a 13″ turret had been the target, twelve shots would have struck it. The probability of a single shot striking was thus $\frac{12}{340} = \frac{1}{28}$.

If the center of the chase of a 12″ gun as protruding from the turret had been the target, twelve shots would have struck it. Of these twelve, four striking obliquely at an angle of less than 30 degrees may be considered as ineffective; eight may be considered as effective, and the probability of a single shot being effective is $\frac{1}{42}$.

If the center of the turret had been the point aimed at with the guns at right angles, the chase of the gun, if pointing to the left, would have received four shots, if pointing to the right, one shot, of which total two would have been ineffective, giving a mean probability of the chase being hit effectively of $\frac{3}{340} = \frac{1}{113}$.

Thus the gun as a whole, with the chase exposed to fire from direction perpendicular to the line of fire and the gun ports exposed in the direction of the line of fire, offers a target of small dimension, and, in the case of the chase, disposed horizontally in the most advantageous manner. Thus the gun proper is only moderately vulnerable, and has small probability of being struck effectively.

The carriage and platform and their gear, including the elevating gear and loading gear, and mechanism for controlling the training gear and ammunition hoist, below, are exposed in the same manner as the breech to fragments of projectiles entering the gun ports and exploding, and their vulnerability is greater than that of the breech of the gun, though in the case occurring at the Yalu, cited above, none of their gear was disabled.

The gun's crew assembled around the breech is exposed in the same way, and is more vulnerable. All its members were killed in the case cited. On the other hand, the number of the crew is small and if the precaution has been taken beforehand of training other men in the duties, the crew or part of it can be replaced.

This assemblage of objects near the breech of the gun presents by far the most vulnerable feature, though they can be reached only by projectiles entering the gun ports. These projectiles are not limited in size; the smallest R. F. projectile entering and exploding could inflict irreparable injury, while, if it struck the chase of the gun, it would be without effect. It might be pointed out at this point that the gun ports as now fitted, for the reason just mentioned, are most dangerous targets, but shields carried externally could be devised, which, while moving with the gun, would effectually close the openings.

The fixed part of the turret extending to the armor deck, properly covered above by a platform of sufficient thickness to catch fragments, and without connection with the objects inside, so that bulging or displacing slightly will not affect the objects inside, offers a perfect protection (speaking in the comparative sense) for the supports of the movable parts of the turret and for the ammunition tubes, while the training gear if properly placed below the armor deck would enjoy a similar protection.

Thus 12″ turret guns on a seagoing battleship, considered as a whole, from the point of view of protection, present a vertical cylinder extending from the armor deck to the top of the movable turret, a vertical target of a total area of 750 to 800 sq. ft., in usual cases, which is completely protected over its whole surface except at the gun ports which present two elliptical areas of about 12 sq. ft. each, with a vertical diameter of 4′ 3″, together an area of about $\frac{1}{32}$ of the total area of the vertical target. This area is of a most vulnerable nature, though the vulnerability could be reduced if not entirely annulled by the fitting of port shields. This cylinder carries in addition, when the guns are trained perpendicularly to the line of fire, a horizontal area about 20′ long, 20″ high at the outer and 40″ at the inner end, making a target of about 30 sq. ft., about $\frac{1}{25}$ of the whole area, of partial or moderate vulnerability and small probability of being struck effectively.

Thus on the whole, assuming that the gun ports are protected by shields, the system composing the heavy turret guns, their fittings, and accessories, is well protected, offering but very small vulnerable areas, with slight probability of being struck effectively.

VI.

To serve her function the vessel must float, must maintain her floatability against the intrusion of water. This can be done by protection against the opening of breaches through which water might enter and by the reduction of the quantity of water that would enter a breach, or a number of breaches if made.

Water can enter by steady flow only through breaches that are made below the water level. It can enter by swash through breaches above the water line, but near it, the nearness varying with the condition of sea.

Since projectiles cannot reach the vessel below the water, protection against them, as far as floatability is concerned, could be secured if armor of sufficient thickness could be worked on the sides over the region liable both to attack by being emerged and to intrusion of water by being immersed.

A vessel of 70′ beam, rolling 20°, a roll common in seas where engagements would be entered into, assuming for simplicity that she is wall sided in the region in question, would emerge on one side points that were 12.7′ below the surface of the water when on an even keel and would immerse on the other side points that were 12.7′ above the water line. With a 20° roll, the region thus exposed to injury at one time and to submersion at another on the vessel in question would extend over a height of 25.5′ from end to end. On vessels whose side armor is best disposed for protection of floatability, extending in complete heavy and light belts, the region protected by heavy armor extends from about 4.90′ below the L. W. L., to about 1.65′ above, and the region protected by the light armor, from the top of the heavy belt to a mean height of about 3.9′. Of the total height exposed on the above supposition, .255 is protected by heavy armor and .153 is protected by light armor, .592 being unprotected.

The portion behind heavy armor cannot like objects behind turret armor be considered as perfectly protected, for the armor tapers to less than half the maximum thickness, which is about the same as the uniform thickness of the turret armor, from the upper to the lower edge, and from amidships to both extremities, while the mean surface of impact will on the whole be much less oblique than that of the turrets. The region covered by light armor is not protected against breaches from guns of medium caliber.

The parts covered by neither heavy nor light armor, .59 of the total, are exposed to breaches being made by projectiles of all calibers and may be expected to be riddled by those of small caliber in an engagement of any length with an enemy of creditable marksmanship.

Thus, on the whole, on the supposition of a 20° roll, the vessel's floatability is exposed to breaches which would allow the intrusion of water over an enormous area along the total length, of which only $\frac{1}{4}$ is protected by heavy armor and less than $\frac{1}{6}$ by light armor, the protection from which is only partial. The Iowa on the supposition of a 20° roll offers a total surface of 8925 sq. ft., of which 1946 sq. ft. are protected by heavy armor, 555 sq. ft. above and 1391 sq. ft. below the L. W. L., 779 sq. ft. are protected by light armor, and 6200 sq. ft. are without protection.

This supposition of a 20° roll is but moderate. A battleship is expected to give battle in conditions of sea where water mounts much higher on the sides than in a roll of 20° and where actual rolling may occur exceeding this angle.

The conditions are of course less severe where the sea is more moderate, and could be assumed much less severe for coast defence vessels.

The quantity of water that will enter a breach or number of breaches can be reduced by causing the breach to close wholly or in part, by subdivision, and by the presence of water excluding materials.

The use of mats and plugs to close breaches in metal vessels can be considered, at best, but slightly practicable.

The use of materials which, swelling from the effect of water, tend to close the breach is of questionable efficiency, and is limited in its application to a small region covering from $\frac{1}{2}$ to $\frac{2}{3}$ of the height of light armor in the case above cited.

Subdivision is the most effective way. It reduces the quantity of water by diminishing the space to which a breach in the side may give access.

The total space may be considered as divided horizontally into two distinct parts. Water entering on one side of the armor deck is accepted as limited to that side only if so desired. After an engagement of consequence has lasted some time this subdivision must be considered as incomplete, particularly now that the armor deck is subject to contact explosion of projectiles carrying high explosives or large charges of powder entering at an angle above the side armor. The horizontal subdivision by other decks and platforms can be considered at best as only partial.

The vertical subdivision by transverse and longitudinal bulkheads is highly developed below the armor deck. Above this deck it is but slightly developed (the case in question being a battleship as above) and includes the cofferdam above the heavy armor, which is used with or without the obturating material for closing breaches.

The effect of a breach in the side from a projectile above or a torpedo below water on the subdivision in that region will vary, but in each instance the resistance of the thin plating of bulkheads even to fragments of small dimensions is very slight. Access will be made not only to the compartments in which the breach is made, but also to other compartments in the line of the trajectory of a projectile not exploding, and to all compartments in the neighborhood in the case of a projectile exploding, except where the explosion occurs in coal, which, when well placed, covers in varying thickness part of the top and the whole of both sides of the space devoted to motive power.

The floatability of a well planned battleship will not be destroyed by the filling of the two largest compartments, but her efficiency would be greatly reduced, the plane of floatation being considerably altered, reducing the reserve buoyancy, the stability and the efficiency of the battery and the motive power. It would cause a sinkage sufficient to submerge the top of heavy armor belt.

Further, the efficiency of subdivision will always have a coefficient of reduction depending on the efficiency of the personnel and the fittings for guaranteeing the bulkheads against the openings that are made in them.

A third cause reducing the quantity of water that may enter flooded compartments is the presence of other materials which exclude their own volume from the volume accessible to water. On battleships, light materials for this special purpose are carried only on the unarmored ends, above the armor deck. The obturating materials of the cofferdams also serve this purpose, and the coal as usually stowed preserves about $\frac{7}{10}$ of the volume it occupies. In all three of these cases the subdivision of the space is more or less minute. Whereas, the large compartments whose flooding would be most serious cannot be stowed with water excluding materials.

Against the ram and torpedo, armor protection is not practicable. Destruction or avoidance of the agent is the only method. As the range is zero for the ram and as the guns to which the agent is vulnerable at short ranges are not likely to be found out of action, the probability of being rammed under normal circumstances is small. The probability of being torpedoed on the other hand is greater as the range of the torpedo may be considered at the extreme as 1000 yards. Though the accuracy of fire is small, the agents may be numerous.

These agents as a steady target would be most vulnerable to the fire of the smallest caliber of R. F. guns, but their diminutive size and swiftness may afford comparative protection under certain conditions of attack notwithstanding the development of the secondary batteries and the use of the search lights, and the use of torpedo nets.

Experiments in Italy go to prove that three thicknesses of plating spaced apart, are insufficient to overcome the effects of torpedo explosion. The outer and inner bottom and the wing longitudinal bulkhead will be inadequate, notwithstanding the fact that the wing passage is left empty so as to transmit as little as possible of the force of explosion, and the probability is that the large compartments in wake of the explosion, unless fitted with two wing longitudinal bulkheads, would be flooded and endanger the floatability.

Though, under normal circumstances, the probability of being torpedoed is small, and the probability of being rammed is much smaller, the consequences in each case are most serious.

In sum, the first requisite, floatability, is at best but partially protected. It is in greater danger than the heavy turret guns. The probability is, that the most efficient type of battleship yet afloat while engaging under the conditions for which designed, if stability is not destroyed previously, will sink before all her heavy turret guns are disabled, the turrets having been supplied with port shields.

If additional cost and weight are available for protection they would be more efficiently expended in increasing the protection of floatability by increasing the area above the water line protected by light armor and by increasing the power of the secondary battery against torpedoes, than by adding to the protection of the heavy turret guns.

VII.

To serve her function a vessel must not only float but must float right side up. Integrity of battery and floatability would be maintained in vain if the vessel turned over.

Stability like floatability is overthrown by the intrusion of water.

Water entering in any part will cause sinkage and reduce the freeboard and the range of stability particularly when it causes an initial heel causing capsizing at a smaller angle of heel, but entering in particular parts under certain conditions its effects are serious and pronounced in another way by influencing the quantity or amount of stability within the reduced range, affecting the righting arm, the magnitude of the upsetting moment required to cause a given heel.

This result is produced by the effect on the position of the center of buoyancy, on the length of the metacentric radius, on the vertical position of the center of gravity of the vessel, and on the shifting character of the weight added, the first two affecting the position of the metacenter, the last two the position of the center of gravity, the sum of all effects being the influence on the metacentric height.

The position of the center of buoyancy will probably not vary greatly. The compartments liable to be opened up to the sea will probably not be found, on the whole, to vary far in vertical position from the center of buoyancy found at about $\frac{2}{5}$ the mean draught below the load water line. On battleships with unarmored ends, the riddling of these ends will cause the center of buoyancy to be lowered, but on the other hand the gain of buoyancy by sinking to balance the loss of buoyancy by the filling of low compartments will raise the center. On the whole, the change in position of the center of buoyancy is but a small element in the probable reduction of metacentric height. The means of safe-guard are the same as part of those for floatability; an increase in the protection of the upper compartments by increase in extent of light side armor.

The reduction in length of metacentric radius will be in direct proportion to the reduction of the moment of inertia of the water plane and to the increase in the volume of displacement.

The accumulation of water in the course of an extended engagement may materially increase the volume of displacement, but the effect is not so serious on this score as it is in diminishing the reserve buoyancy and reducing the range of stability.

The effect depends as for floatability on the amount of water that enters; the inadequacy of the protection is best remedied as in the case of floatability by increasing the extent of light side armor.

The probable reduction to the moment of inertia of the water plane in an engagement is most serious. This is the largest factor that enters to determine the range of stability and the amount of stability in this range; it is the great reduction in the moment of inertia of the water plane caused by the edge of the deck going under or otherwise, that causes capsizing in the usual cases.

If the vessel floated on an even keel in a smooth sea, the danger would be very small except in the cases of battleships whose belt armor is of limited extent leaving large portions of the water plane on the full ends exposed or only partially protected by the presence of water excluding materials.

But when the vessel rolls even slightly, about 3°, her heavy belt is submerged and the actual water plane has only the protection of the light belt, which in English types extends in the form of box armor but a limited distance amidships. The light belt is submerged in vessels with complete belts at the moderate roll of 9°, and above its top the water planes have no protection. Here the vessel's sides will have breaches made by projectiles of all calibres, the effect being most pronounced on the side opposite the side struck, where fragments tear off great lengths of plating.

Thus after a prolonged engagement the vessel on rolling will reach at moderate angles points where the moment of inertia of her water plane will be seriously compromised.

Thus the length of the metacentric radius is but partially protected for angles of roll caused by an ordinary sea swell, and is but slightly protected if not altogether unprotected for angles liable to occur in moderate seas in which battleships are expected to engage.

Amelioration lies along the line of increase of extent of light side armor.

The vertical positon of the center of gravity of the vessel will be affected by the quantity of water that enters and its vertical position after entering.

Remarks on quantity of water liable to enter are given above in the consideration of the subject of floatability.

The vertical position of the water will depend on the position of the opening through which it enters and the disposition made of it after entering.

Openings are liable to be made below the armor deck by torpedoes and can be made as above mentioned, by projectiles piercing the heavy belt or entering below the heavy belt when the lower edge is emerged in rolling, which occurs ordinarily at about 8½°, and by fragments projected downward in the blast of projectiles containing high explosives or large charges of powder, exploding in contact with armor deck. It is not likely that such openings below the water line will be stopped in action and in consequence the compartments flooded may be considered as permanently flooded, it not being practicable in most cases to drain to other compartments or pump out while the openings are unstopped.

The position of the water entering below the armor deck may thus be considered as fixed and its effect on the center of gravity of the vessel, which is usually in the vicinity of the load water line, is to lower it.

Openings above the armor deck made through light armor and in the unarmored sides are liable to only intermittent flooding due to immersion from the rising of waves on the side and from rolling. Water is thus able to collect on the armor deck and on the berth deck and gun deck.

The quantity that enters will depend almost wholly on the condition of the sea and the rolling properties of the vessel. For water entering and collecting on the armor deck near the water line, the breaches will be less pronounced, less numerous and more easily closed or partially closed than water entering above a higher deck, but on the other hand they will be more frequently and for longer periods under water; but being a shorter distance above the center of gravity, this water will have a less marked effect in raising the center. In both cases the quantity can be rapidly reduced by an efficient system for clearing the decks, from the gun deck through scuppers or special ports overboard, from the armor deck through special non-return valves overboard or else through a special system of pipes leading to special compartments in the bottom of the vessel, in communication with the pumps, which latter arrangement causes the water entering above the center of gravity to pass below it.

On the whole, the water entering the vessel, even when the engagement is in a seaway, when the arrangements for clearing the armor and gun decks are efficient, will tend to lower the center of gravity.

Water on board is liable to affect the horizontal as well as the vertical position of the center of gravity. Under the influence of gravity it tends to flow toward the side of the roll or heel and increase their amplitude and danger.

It may be looked on as causing the center of gravity under heel to move out toward the center of the buoyancy, reducing the righting arm, or as an upsetting moment that sets in. The effect is proportional to the quantity of water multiplied by the horizontal distance through which it shifts.

The quantity of water liable to enter is considered above.

The longitudinal subdivision below the armor deck will prevent extensive shifting of water except in the case of large compartments partially filled.

On the armor deck partial and complete longitudinal bulkheads or simple "barrages" are or can be fitted to reduce the shifting. On the gun deck usually no means are provided, and accumulation of water on the deck endangers the stability.

In an ordinary case of a battleship of moderate size, water accumulating to a depth of 6″ on the gun deck by running over to the side of the roll will deduct about 10″ from the righting arm, or $\frac{1}{3}$ to $\frac{1}{4}$ of the maximum righting arm.

In the intact condition this reduction would cause the righting arm to disappear and the vessel to capsize at 10 or 15 degrees less angle of heel or roll.

In an engagement in anything like a heavy sea, this element becomes serious ; large quantities of water are liable to collect on the berth and gun decks, and, flowing from side to side without obstruction, to endanger the righting arm at large angles, particularly in the rolls to leeward, where the wind would superpose an additional upsetting moment.

The entering of water on one side below the armor deck, though not shifting, would materially affect this element of stability by causing an additional upsetting moment, an initial heel to the side bilged, reducing thus the range of stability and the effective righting arm during the roll to this side.

This effect could be partially remedied by the admission of water on the other side, but it would be at the expense of reserve buoyancy and the other elements affected by the admission of water in the region in question.

In sum, the protection to stability is partial at best, the two elements, loss of inertia of water plane and the accumulation of water on the armor deck and decks above the armor deck, becoming of increasing consequence as the sea rises.

Taken altogether, for all seas in which a battleship is expected to engage, the protection to stability is less than the protection to turret guns. In an engagement in a moderate sea, under ordinary conditions, the vessel would capsize before all the heavy turret guns are disabled, and where the vessel is of somewhat low freeboard, and efficient means are not provided, and used for clearing water from decks above the water line, and transferring it from one side to the other, where practicable, or flooding other compartments to counteract the heeling effect, under these conditions particularly when the sea is running at all high, the probability is that the vessel would capsize before foundering.

If additional cost and weight are available for protection, they would be more efficiently devoted to increasing the protection to stability, by increasing the extent of light side armor than to increasing the protection to heavy guns.

VIII.

The admission of water will almost invariably be unsymmetrical, and will cause heel and change of trim, affecting thereby various elements of efficiency. The extreme elevation of turret guns as usually mounted being 15° and the extreme depression 5°, a heel to one side of 5° would render it impossible for guns training toward the opposite side to attain a point blank range; a heel of 10° would cause these guns at extreme depression to fire over any vessel engaging at moderate ranges; a 15° heel would make these guns wholly unserviceable, while the gun on the side of the heel could then only attain an elevation for point blank range.

A heel of 3° would submerge the top of the heavy belt, and a heel of 9° will submerge the top of the light belt. A heel of about 8½° will emerge the lower edge of armor.

Thus only moderate angles of heel will materially reduce the efficiency of the battery, and will reduce the protection to floatability and stability, and even expose permanently or periodically all the vitals.

Change of trim will reduce the efficiency of protection to both ends and will affect, in a less marked degree than for heel, the efficiency of the battery. Both heel and change of trim will reduce the speed by increasing the resistance and reducing the efficiency of the screws. They will ordinarily occur together and the total result when pronounced becomes particularly serious in the reduction of stability.

IX.

The protection of what may be called the vitals, the parts containing the elements of mobility, of governability, and the substances of explosive character, situated below the armor deck, has been involved in the consideration of protection to floatability, stability and uprightness.

The weakest point in this protection in all battleships except those recently designed in France, is the lack or insufficiency of provision for catching fragments caused by the explosion in contact with the armor deck of projectiles containing high explosives, or large charges of powder. Experiments in Italy have shown that the armor deck is shattered in the region, and that the fragments of the deck are projected downward with high velocities, which simple plating cannot check.

To protect the objects below, a heavy splinter deck or second armor deck is necessary at some distance below the armor deck, unless the side armor is fitted, as in the English battleships of the Majestic class, to prevent a projectile, carrying high explosives or a large charge of powder, from reaching and exploding in contact with the armor deck.

With the existing dispositions, excepting in the instances named, the protection to the vitals is not equal to the protection to the heavy turret guns. Under the probable conditions of coming engagements, the probability points to the destruction of motive power, or steering power, or boiler explosion before the disabling of all the heavy turret guns.

Additional weight and cost would be more efficient, devoted to a splinter deck or second armor deck, partial if not complete, than to increase of protection of heavy guns.

X.

The protection of the secondary battery, considering its great and increasing importance, like the protection to the other elements considered above, is not in due proportion with the protection to heavy turret guns, though increased attention is now being paid universally to the subject.

The crews of the turret guns are small and constitute but a small fraction of the personnel stationed above the armor deck in action. Casualties among this larger fraction will be great. The destruction in the Chino-Japanese engagements, to personnel and objects, unprotected or protected only by shields, was terrible.

The case of the Chen Yuen, at the Yalu, may be cited. None of her heavy guns were injured, and yet 76 per cent. of her crew and officers were killed or wounded.

The explosion of projectiles produced terrible effect on everything unprotected; exploding between decks, whole sections of objects on both decks were disabled, and the effect was proportionally large for rapid-fire projectiles of small caliber. A 6-pdr. projectile exploding in a military top of the Ting Yuen killed seven men, probably all those present. The usual effects of such explosions must be of serious consequence in their terror or panic producing effects.

Additional protection, increase of light armor tending to reduce the number of explosions on the inside, would be more efficient than additional protection to heavy turret guns.

Referring to military tops, it is to be noted in this connection that the model represents the masts as rising and falling like the turrets, though no attempt is made to meet the practical impossibilities of the disposition.

As the fire of top guns could be most effective under certain conditions, at short ranges, particularly against the tops of barbettes, and uncovered redoubts, and as the exposure is very great, and the top guns, as shown in the Chino-Japanese war, cannot hope to survive for this close range, it would be a great gain, if some method could be devised for preserving their integrity until the desired moment. Though it is practically impossible to raise and lower the mast, it would not be so difficult to raise and lower the top or tops, leaving the mast standing permanently, needed as it is for signaling. The damage done by shell hitting the masts is not great; they pass through before exploding. The mainmast of the Ting Yuen at the Yalu was struck twenty times without undermining its power to sustain the top.

The same slight effect was noticed in masts and smokestacks generally. One smokestack of the same vessel was struck forty times without seriously affecting its efficiency.

The probability is that late in engagements the masts could still sustain the hoisting of tops and their contents. This operation, as well as the housing of the tops below deck with perhaps slight surrounding protection, the securing in place after hoisting and the securing of the masts, present obstacles which though great, are not impossible of being surmounted.

The idea need not be limited to the usual military masts, but could be applied to platforms raised on one or more supports in various parts from housed positions to positions of various elevations carrying light guns. This would add to the protection of the objects least protected. This feature of the model can be disposed of with the remark that it contains the germs of suggestive possibilities for useful application for purpose of protection, though in the form presented it is utterly impracticable and is unaccompanied by any attempt to meet the practical difficulties involved.

XI.

Summing up the results of the consideration of the relative protection of the heavy turret guns and the other elements of efficiency of a vessel of war as embodied in a battleship, it has been found that the latter, floatability, stability, uprightness, vital organs, secondary battery, and personnel, each and every one, are protected in a less efficient degree, supposing the use of shields or doors for the ports of the turret guns.

To advance toward the equality of protection that would produce the highest resultant efficiency of the vessel, toward the infliction of the maximum amount of injury under the conditions for which designed, toward arriving under such intended conditions of engagements, at the desired point where the offensive and defensive power would disappear together, when the last of the personnel and secondary battery would be destroyed, the vitals pierced, uprightness undermined, and the last heavy turret gun disabled at the moment that the vessel foundered, capsizing as the last vestige of buoyancy went under; to advance toward this ideal combination, it would be more advantageous to expand effort available for protection in increasing the protection of the elements enumerated rather than in increasing the protection of the heavy turret guns.

To subserve this purpose most effectively the effort should be directed toward the increase of the area covered by light side armor, employing it as much as possible for the protection of the secondary battery, and toward the working of a heavy splinter or armor deck well below the usual armor deck, and, where sufficient weight is not available, the division of the available deck armor between two decks instead of confining it all to one deck.

Thus increase of protection to the heavy guns of a battleship does not present a reason of weight for the adoption of a different mount. Heavy turret guns as now mounted may be said to be over-protected.

From the standpoint of protection, if the mount is adopted for other reasons, it would be well to provide for the possibility, where desired, of continued fire from the elevated position with adequate supply of ammunition without returning to the housed position for loading. For it would be better to invite fire on the gun than to have it concentrated on other elements less protected and equally essential to efficiency, particularly as the gun presents its small and slightly vulnerable target above the upper deck where most of the shots aimed at it would miss entirely, which, if aimed at other parts along the hull, though missing these parts, would hit the hull, many of them inflicting damage that might be of serious consequence.

Referring to the target (Fig. 9), it will be seen that if the center of the turret on the upper deck had been the center of fire, 129 shots would have passed over the vessel, wide of the turret, which, if the center of fire had been the water line, would all have struck the hull of a vessel of 17½′ freeboard.

Of course it would have been unwise in the enemy to direct fire on the turret or turrets, instead of the hull, but the former offers to a gunner a definite, inviting, vertical target on which to train, which causes shots to be directed on it notwithstanding instructions to the contrary, depending of course on the discipline of the gunners and the intelligence and persistence of those directing the fire. In the Chino-Japanese engagements, the objects offering vertical targets, masts, smokestacks, turrets, sponsons, etc., invariably received a concentration of hits. Of course no instructions were given to direct fire on smokestacks.

It may be noted here that the feature of being able to remain and fire in the raised position, would materially enhance the value of the system, from the standpoint of offense, by providing for the events, where the saving of time or increase of rapidity of fire more than counterbalances the reduction of obstruction, or any gain in protection.

XII.

There is not only small advantage along the line of protection in an increase of total protection to the turret guns, but the amount of this increase realized in the system proposed, is only moderate, supposing the guns to disappear for loading each time.

Referring again to the target it will be seen that thirty-eight shots would have struck a turret for 12″ guns, if the center of the turret had been the center of fire. This is the result of deliberate practice in time of peace, in smooth seas, at short ranges, with good marksmen. This excellent marksmanship for even these concurring favorable circumstances, gave only one hit in ten. Considering the limited number of shots that could be fired by guns of a caliber to match the turret armor when attacking it normally; considering the cylindrical form of the turret, offering oblique surfaces for impact; considering the slight probability of a projectile, of large caliber, directed against the turret, striking the chase or a gun port; considering the fact that the chase of the gun, even if disposed most favorably for attack, at right angles to the line of fire, offers but a narrow rectangle drawn out horizontally, which, selected for the center of fire in the target, would have been hit only once in thirty shots, and that the chase is cylindrical in form and of great resisting nature, so that but few if any, of the total number of shots striking, of the ordinary calibers that would be directed against it, would be effective; considering these facts, it is evident that in the conditions of battle, the heavy turret guns as at present mounted, are but slightly exposed. (It is assumed, as above, that doors or shields exist protecting the vulnerable gun-ports. As a matter of fact they are not fitted on any turrets now in existence, but, as mentioned above, there is no great difficulty in the way of fitting them, and this point should not enter to throw out the conclusions as to the system. It may be added that, with the turrets now afloat, a shot would be effective striking anywhere within the area presented by the port, when presented direct, except perhaps, in the case of a very small projectile striking the outer part of the annular surface presented by the muzzle of a gun. A projectile entering the bore to score the wall and strike the breech plug if closed and explode, or to pass through into the turret if the breech is open, or striking on the outside of gun, glancing along the surface of slight incline to enter the port and explode inside; under either of these conditions the probabilities of disabling the guns are great, even for projectiles of very small caliber. As mentioned above, taking into consideration the large number of shots fired by rapid-fire guns, the probabilities are that in an engagement many projectiles, if fire is properly directed, will strike this area. In the case of the target cited above, the center of the port presented direct being the center of fire, twelve shots would have struck it, or about one in twenty-eight. The probabilities would be smaller in action for the reasons cited above; but the large figure indicates the great exposure of this vulnerable point).

The disappearing system as proposed reduces the exposure to practically zero while the guns are below deck, provided the cover is sufficient for protection from above, and the amount of exposure of the turret guns usually mounted being small as just pointed out, the gain in reducing this amount to zero is equally small. This gain lasts while the guns are below deck which would probably be about $\frac{2}{3}$ of the time. When the guns are in the firing position the exposure is greater than that of the turret guns, incident to the protection of only light armor, which would offer probably about $\frac{1}{2}$ to $\frac{1}{3}$ the resistance or protection of heavy turret armor.

If only part of the guns appeared at the same time, an operation necessary for the realization of the increase of angle of fire, the enemies' guns could be concentrated on them, to be shifted to the others replacing the first when they disappeared. Under these conditions the guns with their inferior protection though exposed but about one-third of the time, would receive not a great deal less than the same total amount of fire. In addition the guns with their accessories and fittings are more delicate and more easily damaged in the proposed system.

The total possible gain of protection by the proposed system thus depends on the length of the time spent in the raised position of greater exposure compared with the length of time spent in the loading position of greater security.

Considering the time required in lifting the weight through the altitude needed, the guns beginning to be exposed the moment the top of the shield rises above the deck, the time required for training to the bearing of the enemy, for deliberation in aiming on account of the unsteadiness of the platform, for training back to the position for disappearing and for descending gently to the position for loading; considering that during all this time, probably one-third of the total time, the more fragile objects are under greater exposure, the resulting total gain in protection realized by the system can be but moderate under the best conditions of solution of the mechanical problems.

Thus, in sum, there can be but slight advantage in increasing the total protection of turret guns, and the maximum possible gain in total protection to be derived from the proposed system is small and will depend on the perfection of the mechanism. Thus, from the standpoint of mean total quantity of protection there is not sufficient advantage in the disappearing system proposed to warrant a departure from the usual turret mount. However, if the property of remaining at will in the raised position is reserved, the nature of the protection which is constant in usual cases will be variable at will with the disappearing guns proposed varying from a minimum sufficient for projectiles from rapid-fire guns, to a maximum greater than that of the heavy turret guns.

The exposure of the guns will vary between wide limits during all probable engagements of battleships. During times when the probability of being hit by projectiles from heavy guns is small, the protection to heavy turret guns in usual cases is excessive and out of proportion to the exposure; the great thickness of armor is a useless weight ; thickness sufficient for projectiles from rapid-fire guns would be sufficient.

During the times when the probability of hitting with heavy guns is almost certain, an absolute protection for the heavy guns would not be excessive; at moments when the power to withdraw the heavy guns entirely from exposure might be most valuable, particularly, if perchance, the other heavy guns had already been disabled ; at these moments of close range the time required for sighting is small and the time of exposure with the proposed system in order to use the guns' powers of offense is resultantly small and could probably be regulated without great delay of fire to correspond more or less to the time of loading for the enemies' heavy guns.

On a vessel of war, where everything is compromise, where every addition to one element entails a sacrifice to other elements, protection is best when it is proportioned to exposure. With the variable exposure of the guns of a battleship, the protection afforded by the disappearing system proposed, varying more or less at will from a minimum sufficient for projectiles from rapid-fire guns to a maximum greater than the protection afforded by a heavy turret, is superior in *quality* or nature to the protection of heavy turrets.

Moreover, this variable property permits the regulation, within limits, of the gun protection to suit the protection of the other elements, which together may be called the hull. Under certain conditions of engagement, the full possible protection may be reduced and a corresponding increase in the offensive power realized. For instance, engaging bows on in a smooth or moderate sea at moderate ranges or in a heavier sea at shorter ranges, the after guns would remain in the raised position, the forward guns alone disappearing after firing. The exposure of the after guns would be somewhat increased, as it would last during the loading period of the forward guns and the partial protection offered by these would continue only while they were in the firing position; but this protection would be ample under the conditions and the rapidity of fire of these guns could be increased and the advantage of their increase could probably be realized without conflicting with the fire of the forward guns. Under these conditions the protection would be adequate, while the offensive power would be nearly double that of guns mounted in the usual manner where the after guns could not be brought to bear.

There is another difference in the nature of the protection in the two cases of ordinary turrets and of the system proposed arising from the moral effect on the personnel of the guns. The consciousness of invisibility would give to the disappearing crew a strong sense of security out of proportion even to the actual security while the same invisibility would cause the crews of attacking turrets to have a sense of disparity of security out of proportion to the reality. The disappearing crew would feel at advantage, and the crew of the attacking turret of usual form at a disadvantage, causing a marked effect on the efficiency of the service in the two cases to the advantage of the disappearing system.

Summing up the comparison of the protection in the two systems it is found :—

That the possible mean total quantity of protection does not differ largely; the slight difference being in favor of the disappearing system. That the nature of *quality* of the protection differs; that for the disappearing system being superior on account of its variability, allowing adjustment to correspond to the exposure and to the relative protection of the hull, and on account of its moral effect on the guns' crews, causing a disparity in the sense of security due to the element of invisibility favorable in the case of both crews to greater efficiency of the disappearing crew.

Combining quantity and quality the resultant protection is superior in the case of the disappearing system.

Summing up the comparison of the total effective power of heavy battery it has been found that in the proposed system, (1) the effective offensive power has been increased by the increase in angle of fire overbalancing the loss in rapidity of fire. (2) The protection is superior on account of the possible maximum protection being as great or a little greater, while the adjustable nature makes it more adaptable for shipboard, permitting adjustment to correspond to the exposure and to the relative protection of the hull, while a moral effect on the crews is produced to the advantage of the system.

Combining offensive power and power to use same, the resultant total of effective power of the main battery is greater in the case of the disappearing system.

However, as stated above, the gain in offensive power depends wholly and the gain in protection partly on the efficiency of the mechanism.

XIII.

Another important element in naval design besides the power of the main battery is involved in the question of weight, which differs in the proposed system from the usual turret system.

Armor of one-third to one-half the weight of heavy turret armor would suffice for the heavy guns. The saving of two-thirds the weight of heavy turret armor would amount to about 120 tons for a pair of 12″ guns. For two pairs the total saving would be about 240 tons.

On the other hand the mechanism required for raising the necessary weight, 120 tons, through the necessary height, 6 feet, in a reasonable time, 15 seconds, once every three minutes would require an addition to the weight of the hydraulic plant of a 12″ turret of about 30 tons, including additional pumping power and the quantity of water involved, one or more accumulators and a small air compressing engine for same, additional piping and fittings, account being taken of the fact that training and lifting will not take place together.

It may be remarked at this point that the additional weight and power required would be materially reduced if the energy of recoil and the energy of descent could be partly utilized to store up energy for ascent. It would be practically impossible to utilize the energy of recoil on account of the difficulty of connections to the accumulator, but the difficulty of utilizing a part of the energy of descent is not so great. Taking the additional weight for the two 12″ turrets at 60 tons, the net weight saved would be about 180 tons. With the 8″ guns, the conditions would not be exactly the same. It would be advisable, on account of their more rapid fire, to keep them in the raised position, except when a 12″ gun wishes to fire across the position. In consequence, it would not be advisable to reduce the turret armor to the extent taken for the 12″ guns.

On the other hand, a single plant amidships could serve for all four 8″ turrets and the additional weight of hydraulic plant would not be proportionally so large as for the 12″ turrets. (A single central plant might serve for all the turrets with an economy of weight.)

It may be taken that only sufficient weight is taken from the turret armor to compensate for the small increase in weight of hydraulic plant, and that the result does not affect the total weight.

The total saving in weight would thus be about 180 tons.

This amount is less than the saving in the case of simple barbette guns, and is less than the saving in the case of barbette guns protected by shield armor as on the English battleships Barfleur and Centurion, but it would still be a valuable saving, sufficient to aid materially in armoring a splinter deck over the boilers and engines or in increasing the extent of light side armor.

XIV.

Besides the general ideas or principles involved in the model, as considered above, there are certain necessary inherent features of this system which influence the desirability, possibility, and practicability of its application on board ship.

1. An architectural feature is involved in the change in the position of weights.

Supposing the thin armor carried by guns to be about one-third the weight of turret armor and the lift to be 6 feet, the raising and lowering of the weight involved in the 12″ guns would cause a change of about $\frac{1}{15}$ in the metacentric height. If in addition the 8″ guns were mounted on the same principle and had a lift of 5 feet, the total effect would be a change of about $\frac{1}{10}$ in the metacentric height.

In passing from one position to the other, the radius of gyration of the vessel would be altered, increasing for the raised position.

The reduction in metacentric height would combine with the increase of radius of gyration to cause an increase in the period of roll for the raised position, which would give a steadier platform for the guns in the firing position.

Since the vessel would be designed for adequate stability with the guns in the raised position, the effect of this feature of the system is advantageous, both to stability and to steadiness of gun platform, though the effect is but small in extent.

2. In seeking to utilize the possibility of firing across the positions of other guns there will be danger of injuring the guns that may be in the operation of rising at the moment of the firing. This is a serious danger for the conditions of battle, however trained and careful the gun captain may be; in fact, it is dangerous to allow a gun the possibility of training to the extent of bringing into the field any other gun mounted on the same level. To remedy even partially this danger there would have to be a single mind in constant knowledge of the position, raised, lowered, rising or falling, of every turret, with the power to influence the firing of the guns in accordance with such knowledge. The difficulty of providing a single mind with such knowledge and with such control is a serious detraction from the plausibility of wholly utilizing for fire angles that are subtended by turrets. For volley firing, for a single volley or for successive volleys, in which the moral effect of invisibility, of appearing to fire and then disappearing, referred to above, would be great; for such firing, where the commanding or other special officer would direct and control the fire, the danger to guns would be less.

3. However efficient the mechanism may be, there must always be a loss in rapidity of fire of any gun. The influence of this loss has been considered above. Its effect will become greater and greater as the caliber decreases; the time required for the additional operations increasing in its proportion to the total time.

4. As mentioned above, the presence of turrets on the upper deck would cause many shots to miss. With the disappearing system the hull would receive much greater punishment, while, as demonstrated above, it is the weaker part.

5. The increase of mechanism, with its accessories and fittings would increase the complexity, and every increase in complexity increases the probability of accident and the danger of some important part not working properly in action when the smooth working of every part is of paramount importance. Simplification would result from the use of explosives or chemicals to shoot the weight up gently; but at present such a method is beyond the sphere of practical possibility and reliance must be placed on hydraulic power with or without association with compressed air, with the complexity of mechanism necessarily incident thereto.

6. A serious mechanical difficulty is met with in providing security when the guns are not in the housed position, against the friction when the guns are raised with the vessel inclined, against inertia of rolling and pitching and against the shock of recoil, the turning moment when a single gun is fired, and the shock when struck by a projectile. To reduce the friction in rising, the bearing surface must not be large, and rollers would have to be introduced to reduce this friction; and yet these bearings must form a rigid support or else the shocks and forces will affect the ram on which the system is supported, reducing its efficiency, if not destroying its action. However efficiently this difficulty may be met, the system will always be more fragile and more liable to be jammed or otherwise put out of working condition.

7. The rising will cause mechanical difficulties to be involved in the joints for the supply of power to the guns for elevating, loading, etc., for the supply of ammunition, particularly when the gun remains elevated, the transmission of power controlling the training gear and ammunition hoists, and in all other connections between the guns and the outside—difficulties in which electricity alone could avoid the undesirable features of telescopic joints.

Thus, though slightly favorable to stability and steadiness, the features inherent in the system involve complexity and liability to accident, a loss in rapidity of fire, an exposure of guns to danger from other guns on board, an increase of punishment to the hull, serious mechanical difficulties, and greater fragility or liability to be jammed or put out of action. The gravity of these objectionable features on board ship is evident.

XIV.

The details of the features of the method proposed will not be considered at length for the reason stated in the beginning. The applicant could not have proposed any reasonable details. It would be impossible for any one but an expert to even approximate reasonable designs for the system with its complicated mechanism.

It will suffice to point out simply certain features of two sketches, Figs. 11 and 12, furnished by the applicant:—The proportions are not good; scantlings exaggerated; weight of movable parts enormous; thickness of armor fabulous. The box form of armor is inefficient and without support. It would be impossible to make armor of the form indicated and impossible to support it efficiently. It is impracticable to attempt to have two positions for disappearing; the weight of armor required would be utterly inadmissible. The only practicable form that would fulfil the idea of the form proposed, would be something like that shown in sketch Fig. 13, which represents the gun run out. No adequate method is shown or proposed for sustaining or securing the lifted weight against the friction when the guns are raised with the vessel inclined, against the inertia of rolling and pitching, against the turning moment when a gun fires, against the shock of firing and the shock when struck by a projectile. The combination of rollers and hydraulic ram presents the difficult situation that if supports are fitted to take the above forces and shocks sufficiently rigid to protect the ram from their effects, the rigidity will interfere with the efficient working of the rollers; while, on the other hand, if the rigidity or support is not secured, the forces and shocks will affect the ram.

It would be difficult, if not impossible, to pack the ram efficiently with its angular form, particularly on its inner surface, which could not be reached for adjustment; further, this form of ram entails excessive weight and is easily injured and thrown out of working order.

No system is shown or explained for transmitting power into the turret for the purpose of elevating and loading, or for transmitting motion from the turret for controlling the training and the supply of ammunition. With the lifting movement, it is difficult to make any transfer of power or even of force or motion from the outside to the turret, or *vice versa*. As stated above, any but electrical arrangements would require long telescopic joints of difficult and more or less fragile construction.

No method of hoisting ammunition is shown or described, though the vertical movement makes this feature a difficult one with the form of ammunition tube adopted. The ammunition tube as shown is inadmissibly small.

Thus, in sum, the features of the method proposed do not face many necessary and difficult problems, theoretical and practical, involved by the system, and those that have been faced have not been solved within the remotest degree of practicability.

However, the method involves features which, in proper shape, are probably the best adapted to use on board ship, the use of a simple vertical rise accomplished by a hydraulic piston acting directly.

The simple direct rise in the disappearing mount is not new. It was employed on shore in France toward the end of the last century in a crude form where the platform carrying the gun was carefully counterbalanced and only moderate force from hand power sufficed to cause the rise through a large altitude. It has recently been perfected in France by Canet for use ashore on an armored turret raised directly by a hydraulic ram, the fall being sufficient to cause the gun-port to pass below the level of the pit over which the gun fired, the gun having recoiled till its muzzle entered the turret, whose top when down rests on the rim of the pit. It has, however, never been adopted on board ship.

A more definite idea of these two principles cited can be had from sketches Figs. 17 and 18 of a form that suggests itself for putting them in a more practicable shape.

The turret is of thin armor with sloping sides, and, like the barbette, is circular in section like the barbettes found in connection with turret guns on French battleships. The gun, the turret, and all its contents are carried on a central built-up tube somewhat similar to the tube of the Farcot system of turret adopted on French vessels, though cylindrical over a greater part of its length. The base of the tube ends as a ram plunger in a hydraulic cylinder fitted on the inner bottom, with a stroke of 6 feet. The training gear is hydraulic, fitted as on French battleships, though the drum or band on the central tube, over which the chains reeve for revolving, carries a feathered jacket or sleeve that permits the free vertical movement of the tube, while it transmits the movement of rotation.

Separate ammunition tubes are fitted, the central tube not being used for this purpose on account of the difficulty presented by the rise. These tubes lead to the loading platform, and when it is desired to continue fire without descending to load, the ammunition is wheeled on a car around a track until it comes beneath the rear end of the gun, and from this position is hoisted into the turret by a hoist fitted to the turret cover. In the raised and trained position the weight rests on the ram. In the housed position it rests on a ring base covered by hard rubber for a buffer, supported from the armor deck in the usual way. At the passage of the central tube, through the decks and platforms there are strong roller bearings, to reduce the friction in the rise, and to offer rigid support for shocks and forces acting on the weight lifted. To this end, the accurate bearing could be insured by having the rollers on part of the circumference adjustable. A guide support, not indicated, is built around the ram just above the cylinder, to save the cylinder from strain.

The barbette is about 30′ external diameter; is self-sustaining, without backing. Gates are cut to allow the entrance of the chase of the guns in descending. These are closed by armor-doors in two sections, both sections closing when the guns are up and completely closing the gates, the upper ones only closing when the guns are down.

The weight lifted is about 230 tons. The diameter of ram is 30″. An accumulator, with air chamber, made up of tubes or pipes, weighing about 7 tons, supplying about 30 cu. ft. of water under a pressure of about 900 lbs. per sq. in., suffices to effect the rise without the assistance of the pumps. Pumps of about 90 horse-power can charge the accumulator in two minutes. Air is kept supplied by a small pump weighing about 500 lbs. The presses for training are fed from the accumulator.

It may be pointed out that the development of the disappearing principle has been principally along the lines employing rocking shafts and levers. The early examples, covering the first half of this century, employed the principle of the eccentric and the inclined plane, but the important developments since, excepting the case of the Canet turret, cited above, have employed rocking shafts and levers in single or double pairs, actuated by counterbalance, spring, hydraulic, pneumatic, hydro-pneumatic, and hydraulic-spring power. The rocking shaft lever system has the inherent advantage of being required to lift only the weight of the gun, the recoil gear being below, associated with the raising gear and utilizing or not, for subsequent raisings, a part of the energy of recoil and descent. It has also the inherent advantage of economizing time by returning automatically at recoil to the position for loading, and by permitting the elevation and sighting from below, the gun rising to its firing position all ready for fire. In addition it throws the muzzle forward over the parapet or redoubt or turret for firing.

It is the lever form that has been adopted in all five of the systems cited, notwithstanding the fact that on board ship the unsteadiness of the platform requires the gun to remain in the firing position, personally directed by the gunner, for a period more or less extended, during which time the gun is exposed, though, as demonstrated above, this exposure is not of so great consequence, the vulnerability of the gun not being great and the probability of being hit by projectiles of large caliber being small.

If the gunner follows the gun up, which is more or less necessary on board ship, his exposure would be very great.

In connection with the disadvantage incident on board ship to the impossibility of employing satisfactorily the method of indirect sighting used ashore, on account of the unsteadiness of the gun platform, it may be pointed out that the first Russian ship to adopt the system was a coast defense vessel of the Black Sea squadron, and the three recent battleships having it all belong to the Black Sea squadron. The only vessel carrying the system on the high seas, the Temeraire, is having the guns replaced, abandoning the system, though the system was not abandoned till the guns mounted, which were muzzle loading, became obsolete.

Though it is difficult to draw exact conclusions, the fact that the experiment was not repeated on the high seas would indicate that, on the whole, the system was not considered as entirely satisfactory for adoption on board ship.

The levers require also a large horizontal sweep which will always increase the space required for their action. In the cases thus far adopted on board ship, the guns have recoiled back entirely within the armor defense, though they cannot be said to meet the difficulty due to the great length of recent guns, for the guns on the Temeraire and the Vice Admiral Popoff are of the old short type, and those of the Tchesme and her sister ships are all six mounted in a large redoubt, where space is but a small item.

The mount of the Temeraire, outlined in sketches, Figs. 15 and 16, was the Randel system. The guns were 25-ton guns, and were raised out of towers and barbettes 7 feet high by hydraulic rams acting on bell-crank levers, no use being made of recoil energy, which was taken by usual hydraulic recoil cylinders. The rotating platforms carried the hydraulic training gear. The hydraulic pumps were below the water line, controlled from the platform. When firing against time, the interval between shots for four rounds was one and one-half minutes.

The mounts of the Russian vessels are of the Moncrieff system, simple hydraulic. An outline is given in sketch Fig. 14 of the type used on the three battleships cited above for three pairs of 12″ guns.

The hydraulic cylinders serve the double office of raising the guns and taking up the energy of recoil and descent. They work through the intermediary of a hollow plunger connected by levers with the rocking shaft.

The training gear is of the ordinary type, worked by steam. Water is supplied from an air accumulator, sufficient to raise the gun once without the assistance of pumps.

The ammunition hoist is of ordinary type, worked by steam. The guns together weigh 100 tons, and the carriage complete, including training gear, accumulator, etc., weighs 120 tons and costs about $75,000, which compares favorably with carriages for ordinary mounts. The mechanism has worked well in service. It is to be noted that the weight to be lifted is only about $\frac{3}{7}$ of the weight lifted in the proposed mount, and the rise, 4 feet, is only $\frac{2}{3}$ as great, while using the lever system avoids those serious difficulties of joints, and bearings, and supports cited above. But the guns and gunners in the raised position are entirely exposed, and, as mentioned above, the lever system is unsuited for carrying up protection,—which is essential on board ship, except under exceptional conditions of sea, on account of the length of time it is necessary to remain in the raised position in order to sight properly, the platform being unsteady and indirect sighting being impracticable.

These three vessels realize a great saving of weight, practically the total weight of three turrets, but it may be pointed out that weight is lost in the adoption of an armored redoubt instead of barbettes, and the protection is insufficient even for the lowered position of the gun on account of the entire lack of cover, leaving complete exposure to plunging fire.

Thus, though the cases cited are interesting as examples of the disappearing principle afloat, they only fulfill the object of saving of weight and utilizing invisibility for protection, without attempting to realize any increase of angle of fire, without realizing an increase of mean security, and without attempting to realize any security for the guns in the firing position, while they throw no light of experience on the practicability of the difficult mechanical features inherent in the system. They show the practicability of employing hydraulic power, in connection with an air accumulator, to perform the work of lifting the weight; but even here, the work is only one-quarter of the work necessary in the proposed system.

SUMMATION AND CONCLUSIONS.

A.

Examination was requested on the ideas or principles involved and illustrated without reference to details. Investigation showed, however, that the entire value of the system depends on the success of method or the perfection of details, and, in consequence, it has been necessary to pass in review the main inherent features of the method, and the main features of detail proposed, in order to form a just estimate of the value of the system, and the value of the model.

B.

The examination has led to the establishment of facts as follows :

I.

1. The model, as a piece of workmanship, is in good proportion, and indicates extended thought, ingenuity, care, perseverance and patience in building.

2. The object of the system is to increase the effective power and efficiency of the main battery by increasing the effective angle of fire and the mean security of the heavy guns.

3. The main features in the proposed accomplishment of this object are the use of an unobstructed flush upper deck and the use of disappearing mounts in a form to permit fire over gun positions while the guns are below deck.

4. The second feature has not been adopted in any naval design, and, as far as research showed, has not been previously proposed.

II.

FEATURES OF A FLUSH UNOBSTRUCTED UPPER DECK.

1. The realization of this feature presents disadvantages and difficulties, the most important of which are connected with the sweeping away of mounts for guns of the secondary battery. These disadvantages and difficulties are not, however, without the possibilities of adequate remedies.

C.

Effect on Effective Power of Main Battery.

I.

EFFECT ON OFFENSIVE POWER.

Gain in Angle of Fire.—1. The possible gain is large.

2. The gain on the Iowa, by complete application, would be $\frac{1}{3}$ for the 12″ guns and double for the 8″ guns. Taking the amount of offensive energy generated as the term of comparison for two batteries, the mean gain would be .7, or the mean angle resulting would be 1.7 times the mean present angle.

Loss in rapidity of fire.—1. It is impracticable to have more than one position for disappearing. If the guns are lowered after each round, loss is incurred in lifting, in training to the bearing of fire, in training back to the position for lowering, and in lowering.

Assuming a perfected mechanism these losses would cause a loss in rapidity of fire estimated at $\frac{1}{6}$.

2. With imperfect mechanism, loss could be double the above figure or even larger.

3. The resultant effect on offensive power assuming perfected mechanism would be an increase in the proportion of 1.45 to 1. It would be less with imperfect mechanism, depending on the degree of imperfection.

II.

EFFECT ON SECURITY.

(*A*). *The Extent of the Need of Additional Protection to Heavy Guns.*

I.

PROTECTION OF HEAVY GUNS AS MOUNTED IN TURRETS OF USUAL FORM.

1. Heavy turret armor may be taken as an over match for guns.

2. The gun proper, chase and breech are but slightly vulnerable and have slight probability of being struck effectively.

3. The platform and all gear associated with it is vulnerable but runs very slight chance of being hit if doors or shields are provided for gun-ports.

4. The gun's crew is exceedingly vulnerable but runs slight chance of being hit if gun ports are protected.

5. Fixed portions, all within barbette or below protective deck, may be considered as having perfect protection.

6. On the whole, the system comprising heavy turret guns as usually mounted is well protected.

II.

THE PROTECTION OF THE REST OF THE VESSEL.

1. *Protection to Floatability.*—In a sea-way, but a small fraction of area exposed to both submersion and emersion is protected by heavy armor, and a smaller fraction by light armor. The ameliorating measures are of but slight importance, except the one of developed subdivision. Protection to floatability is inferior to protection to turret guns. Increase would take the line of increase of area of light armor and increased power of secondary battery.

2. *Protection to Stability.*—The principal factors of danger, the loss of moment of inertia of water-plane and the accumulation of

water above the armor deck, are badly exposed in a sea-way. Protection to stability is less than protection to turret guns. Increase would take the line of increase of area of light side armor.

3. *Protection Against Heel and Change of Trim* is similarly disproportionate. Consequences of same affect battery and stability and floatability.

4. *Protection of Vitals.*—Weak point; lack of an armored splinter deck. Protection to vitals is less than protection to turret guns.

Increase would take the line of fitting an armored splinter-deck.

5. *Protection to Secondary Battery and Personnel.*—Not in proportion to protection of turret guns.

Additional light armor as a remedy.

Remarks on military-tops as to the feature of being raised and lowered.

III.

SUMMATION OF RELATIVE PROTECTION TO TURRET GUNS AND TO OTHER PARTS OF VESSEL.

1. All features are less protected than turret guns.

2. It is advisable to direct effort toward an increase of the protection of weaker features.

3. The method of procedure would be an increase of the area protected by light side armor, and the working of a heavy splinter deck.

IV.

BUT SLIGHT VALUE CAN ACCRUE BY INCREASE OF TOTAL PROTECTION OF HEAVY TURRET GUNS.

Additional Protection is not Needed.—1. Guns are over-protected.

2. It would be advisable under certain conditions to have heavy turret guns on deck and invite fire on them to divert it from the hull.

(*B*). *The amount of Additional Protection to Guns Afforded by the Proposed System.*

Exposure of Heavy Turret Guns.—As at present mounted, the turret guns are very slightly exposed.

Exposure of Guns in Proposed System.—1. Exposure is reduced to zero while below deck, which position is occupied about two-thirds of the time assuming perfected mechanism; but this reduction is not great.

2. Exposure is greater while above deck which position is occupied about one-third of the time.

3. If the guns descend for loading after each round, what may be termed the mean total quantity of protection will not differ largely in the two systems. With perfected mechanism, the proposed system would realize but very slight additional protection to guns.

(*C*). *The Difference of Nature or Quality of the Protection.*

1. The protection of usual turret guns is constant.

2. The protection of the disappearing guns, remaining above deck or disappearing at will, is variable.

3. The exposure of guns will vary between large limits during all probable engagements of battleships.

4. On a vessel of war, which is entirely made up of compromises between conflicting elements, protection is best when only proportional to exposure.

5. The protection on the disappearing system proposed, varying at will, is superior in *quality* or nature to the protection of heavy turrets.

6. The feature of variability permits the adjustment of the protection of the guns in the proposed system to correspond to the protection of hull.

7. The moral effect of the protection is to the advantage of the crews of the guns of the disappearing system.

8. In sum, the variable nature of the protection in the disappearing system gives it a superiority of *quality* over the protection of ordinary turrets.

(*D*). *Results of Examination of Effect on Security.*

1. But slight advantage can accrue from *any* increase of the mean total quantity of protection to heavy guns.

2. The mean of this possible total gain in quantity of protection realized by the proposed system can be but slight, even with perfected mechanism. From the standpoint of mean total quantity of protection, but slight advantage can be realized by deviation from the usual turret mount.

3. The variable nature of the protection in the disappearing system gives it a superiority of *quality* over the protection of ordinary turrets.

4. In sum, the proposed system offers advantages for the security of the guns, but the slight advantage in possible *quantity* of protection, and the decided advantage in *quality* of protection both depend for their realization on the efficiency or perfection of the mechanism.

III.

RESULTS OF EXAMINATION OF EFFECT ON EFFECTIVE POWER OF MAIN BATTERY.

1. The offensive power would be increased in the ratio of about 1.4 to 1, with perfected mechanism.

2. The security of the guns necessary for the use of offensive power would be increased, slightly increased in quantity, and decidedly enhanced in quality, with perfected mechanism.

3. In sum, the effective power would be decidedly increased in both its elements with perfected mechanism.

4. Perfection or efficiency of mechanism is essential to both elements of increase.

D.

Various Features Influencing the Advisability of Adoption.

I.

THE QUESTION OF WEIGHT.

1. In properly designed form, there would be a gain of two-thirds the weight of the turret armor for 12″ guns.

2. A loss of about 30 tons would be incurred in increase of mechanism for 12″ guns.

3. A slight gain would be realized in weight of turret armor for 8″ guns.

4. A slight loss would be incurred in increase of mechanism.

5. The net gain or saving would amount to about 150 tons for the battery in question.

II.

FEATURES INHERENT IN THE SYSTEM.

1. The change in position of weights influences favorably, though in a small degree, the stability and steadiness of platform.

2. The system incurs danger to guns on board.

3. More hostile shots will hit; the hull will receive more punishment, though less able to bear it.

4. Complexity will be increased with increase of liability to get out of order.

5. The system is more fragile and more easily deranged or disabled.

6. Serious difficulty is involved in providing, even partially, against shocks, inertia, and deranging friction.

7. Serious mechanical difficulties are incurred in joints and fittings.

8. In sum, grave difficulties stand in the way of practicability.

III.

FEATURES OF THE DISPOSITIONS PROPOSED BY THE APPLICANT.

1. Proportions, scantlings, weights are all abnormal.

2. Barbette armor is of fabulous thickness, impossible form, and without possible support.

3. Two disappearing positions are provided; an inadmissible feature.

4. No method is shown for security against the forces of vertical friction, inertia, and shock.

5. Friction rollers requiring play are associated with a hydraulic piston requiring rigidity.

6. The form of ram is heavy, fragile, and difficult, if not impossible, to pack.

7. No method is shown of transmitting power into the turret or cage, for purposes of elevating, loading, etc., across the difficult joint between rising and fixed parts.

8. No ammunition hoist is shown, and it would be difficult, if not impossible, to fit one.

9. The ammunition tube is inadmissibly small.

10. In sum, grave practical difficulties are not faced, and the attempts to face others are all inadequate and impracticable, where not impossible, of execution.

11. The disposition involves, however, the idea of the method along which the difficulty of lifting can be best accomplished, that of a hydraulic piston acting directly to produce a simple vertical movement.

IV.

FEATURES OF THE SYSTEMS FOUND ON BOARD SHIP ABROAD.

1. *In the British Navy.*—On the battleship Temeraire. Lever system—Randel type—three short muzzle loading 25-ton guns, mounted singly, disappearing in barbettes; no increase of angle of fire; no protection in firing position; moderate weight; moderate lift; simple mechanism; long use in service; good results for rapidity of fire; example not repeated in British service; guns obsolete being replaced by modern guns of usual type.

2. *In the Russian Navy.*—Four vessels of the Black Sea squadron, three battleships and one circular coast defense vessel. Lever system—Moncrieff type—simple hydraulic in connection with air accumulator. On the battleships six 30-caliber, 12″, 50-ton B. L. R., mounted in pairs, disappearing in a single armored redoubt; no increase in angle of fire; no protection in firing position; moderate weight; moderate lift; simple mechanism; successful tests and use in service; looked on with favor.

3. All five mounts are of the lever system, which involves moderate weight to lift and simple mechanism, but is not adapted to increasing the angle of fire and the carrying of protection for the firing position. All demonstrate the efficiency of hydraulic power to accomplish the work of lifting, though the amount of work is but a fraction of the amount required by the proposed system. The systems do not seek to realize the main objects of the proposed system, and do not involve its principal inherent mechanical difficulties.

E.

CONCLUSIONS.

The facts above enumerated lead to the following conclusions:

I.

1. Realized under perfected conditions, the proposed system would materially increase the power and effectiveness of the main battery by increasing the offensive power, and by improving the conditions of security. The offensive power is increased by the increase of angles of fire, an increase which, under the conditions supposed, would largely overbalance the decrease due to loss in

rapidity of fire, while the efficiency of the security is improved by the variability of its nature, an important characteristic afloat, permitting adjustment to suit exposure, and to suit the relative protection of the hull. By regulating the extent and frequency of recourse to disappearing, the factor which enhances the angles of fire and increases the protection, but which reduces the rapidity of fire, the interdependent elements of offensive power and defense of the heavy guns can be regulated at will to suit the needs of the occasion, a valuable quality on board ship not realized in any existing system.

2. The same would realize a material saving in weight, the saving in weight of turret armor largely overbalancing the increase due to additional mechanism.

3. The same would create a moral force in its own personnel and the personnel of the enemy setting to its advantage in both cases.

4. The same would have an ameliorating effect on the stability and steadiness of gun platform slight in extent.

II.

On the other hand,

1. The power and effectiveness of the secondary battery would be reduced. Remedy would be sufficient on large displacement; it could be only partial on small displacement.

2. The realization of the advantages incident to disappearing, cited above, would entail loss in rapidity of fire. The extent of this loss, affecting the offensive power, would depend on the efficiency of the mechanism.

3. The same would cause more shots to hit, and increase the punishment of the hull, which is already underprotected compared with the heavy guns.

4. The same would cause danger to guns on board if advantage is taken of the feature permitting increase of angle of fire by firing across gun positions. This danger would be small in volley firing in which the moral effect cited would be greatest, where the fire is controlled by a single mind. It would be serious where firing was independent.

5. The system is more fragile than the usual systems, it being practically impossible to provide other than hydraulic support in

the raised position. This could be ameliorated by special provision being made to provide the training gear and the vertical bearings against the forces and shocks acting on the sustained parts.

6. The same would involve greater complexity than the usual systems, increasing the liability to derangement The extent of this disadvantage would depend on the mechanism—being moderate for perfected mechanism but inadmissible for imperfect mechanism. It could be ameliorated by providing for abandoning the disappearing feature, if need be—the guns remaining constantly above deck.

7. The same would involve mechanical difficulties in joints and fittings, difficulties that are serious but not insurmountable.

III.

Summing up, the ideas of the system offer advantages; the principal advantages of increase in effective power of main battery and economy of weight and the incidental advantages of a favorable moral effect and favorable effect on stability and steadiness of gun platform, which would preponderate heavily over the disadvantages incurred—disadvantages of reduction of power of secondary battery, reduction of rapidity of fire of the individual disappearing guns, the increase of punishment to the hull, the increase of fragility and complexity, and the difficulties of execution—provided the mechanism for accomplishing the various operations is efficient and substantial.

The necessity of this provision is absolute; with imperfect mechanism, with slowness and uncertainty of action, the gain in effective power of main battery is rapidly undermined in both its elements, in offensive power and in efficiency of protection, while the gravity of the disadvantages increases in rapid proportion.

As to the practical features to be embodied in a system of successful mechanism some suggestions are found in the Farcot system of turret, in the disappearing mounts on the Russian battleships, and in the Canet disappearing turret for land use, but they cover but a small part of the ground; as yet no adequate design has been made or attempted.

Expert design must be entered into in full detail, and must be experimented upon before the final value of the system can be passed upon, or the advisability of its adoption fully considered.

Within the limits of this examination it may be said that the difficulties pointed out above do not appear to be insuperable, while the possibilities for usefulness are large, particularly if their full realization is rendered possible by the adoption of sufficient displacement to allow for raising to a higher degree the weaker hull protection.

But this field for usefulness lies wholly within the domain of the expert. The model is original, interesting, and suggestive, suggests the novel features and possibilities pointed out above, but its field is limited from evident necessity to suggestion alone. Detailed examination, and design, and experiment, three necessary steps between suggestion and adoption, still remain, and it would not be advisable to take them along the lines indicated by the applicant.

* * * * * * *

Attention is called to the points of professional interest which have come up.

1. The disparity between the protection of heavy turret guns and the other elements together classed as the hull. The substantial nature of the exposed part of the gun, and the slight probability of being struck effectively. The need of extending the area covered by light armor for protection to floatability, stability, and the other elements of efficiency, and the need of an armored splinter deck.

2. The grave exposure of turrets from their unprotected gun-ports. The extreme vulnerability to projectiles entering of even small caliber, and the large probability of many projectiles entering. The practicability of fitting doors or shields.

Editor's Note.—Discussion by members is particularly requested upon this article, the same to be printed as a part of the next number of the Proceedings. Any such discussion should be in the hands of the Secretary by Dec. 10, or as soon thereafter as practicable.

PROFESSIONAL NOTES.

TESTS OF CORN CELLULOSE.

[*Iron Age, June 20.*]

The special board appointed by the Secretary of the Navy to test the Marsden American cellulose, manufactured from the pith of corn stalks, in competition with the cellulose hitherto used, which is made from cocoa fiber, were carried out at the Indian Head Proving Grounds, near Washington, last week. Two cofferdams 6 feet high, 6 feet wide and 6 feet deep, and constructed of ½-inch steel plate with a 4-inch wood facing and 12-inch water compartments in front and with ¼-inch steel plates on the sides and back, were filled with the rival materials. The cocoa cellulose was placed in the cofferdam under pressure at a density of 7 pounds 8 ounces per cubic foot, thus requiring 810 pounds of material. The Marsden product was inserted at a density of 6 pounds 8 ounces per cubic foot, requiring less by over 100 pounds than the cocoa product. The cofferdams were placed at a range of 320 feet from the gun muzzles. The first shot was fired at the cofferdam containing the cocoa cellulose with a 6-inch gun and a 100-pound projectile, which passed entirely through the cover of the cofferdam, making an opening 7 x 9 inches. Water was turned on and in ten minutes commenced to run through the lower edge of the shot hole at an average of ½ gallon a minute. The next shot was sent into the cofferdam holding the Marsden product with the same gun and a similar projectile. The shot passed completely through, making a 7 x 8-inch hole. Water was turned on, but none went through, the material having so expanded that the inflow of water was entirely stopped. At the next test a 250-pound shot was fired from an 8-inch gun, making a 9 x 12-inch opening in the cocoa cellulose cofferdam. Water having been introduced, poured through in 37 seconds at the rate of 1 gallon a minute. The Marsden cofferdam was fired at under similar conditions, an opening 10 x 12 inches being made. Water being turned on, at the end of three-quarters of an hour none was found to have gone through. The 6-inch holes were then immersed for 2¼ hours and the 8-inch 45 minutes, when it was found that the water had only penetrated 2 feet into each shot hole in the case of the cofferdam filled with the Marsden American cellulose, while the cocoa cellulose was found water soaked in every direction in and around the shot holes. Experiments were also made in regard to the action of fire on the two products, by which the Marsden product was found entirely incombustible, while the cocoa material burned in each instance, and twice burst into flames. The official reports of the test are to be shortly laid before the Secretary of the Navy. It is thought certain that the American cellulose will in future be exclusively used in the new war ships, provided its durability is equal to that of the foreign product. This feature can only be determined by time. In point of cheapness, the American product has the advantage over cocoa cellulose.

WAR KITES.

[*United Service Gazette, May 25.*]

Major-General Lord Methuen, C. B., C. M. G., presided at the Royal United Service Institution on Wednesday last, on the occasion of Lieutenant B. F. S. Baden-Powell, Scots Guards, reading a paper giving much novel and instructive information regarding kites and their uses in war.

The gallant officer remarked that, after having tried all sorts of forms and shapes and sizes of kites, he was able to put down the following undoubted facts as the results of his preliminary labors :—(*a*) That a properly constructed kite can be made to fly in the very lightest breezes, and that, as a rule, the higher it goes the better it flies, since the wind at a height becomes steadier and more powerful as we ascend. The days on which a kite cannot be flown through lack of wind are very few. (*b*) That by fitting "side lines" to the kite it can be steered out of the wind course—that is to say, made to fly on either side of the direction of the wind, and this to an extent of at least 45 degrees (under favorable circumstances 125 degrees, or 62½ degrees on each side). A kite can thus always be made to fly over any spot within a quarter of a circle away from the wind, and as far as its string will reach. (*c*) That in an average wind, say, 12 miles an hour, a kite can lift off the ground a weight equal to about .3 lb. per square foot of area, so that a kite of 500 square feet could lift a man. (*d*) That if the string of a kite carrying a weight breaks, the kite forms a good parachute and descends gently. (*e*) The length of the string is practically unlimited, since when a kite has taken out all the string it is able to lift (which may amount to nearly a mile), the end of the string may be affixed to a second kite, and so on. (*f*) That by suitable arrangements of cords, etc., a kite may be made to fly very steadily without any possibility of its "capsizing." (*g*) That on a perfectly calm day a kite can be made to float in the air, so long as it is towed along at a rate of at least 4 miles an hour.

It may often be desirable in military operations to communicate between bodies of troops when the usual methods cannot conveniently be carried out. A post high in the air would often then be of value. It would be specially useful to columns on the march in a broken or thickly wooded country, and under such circumstances that it would be dangerous to detach signalers to outlying posts of vantage. A kite could generally be towed along with a moving column, or could be kept floating above a camp. Even at night it might be found practicable to signal with some form of lamp. With this object small kites have been flown, carrying on their strings an ordinary signaling flag, so arranged that a man holding a pole on the ground, and moving it in the same manner as a flag, causes the flag to "wag" as desired.

A kite lifting a camera high in the air can be made to hover over any given spot, more or less to leeward, and the photographs thus taken might be of the greatest value. There is practically no limit to distance to which it could be sent, and thus plans of fortifications, camps and positions might be obtained, as well as accurate surveys of the country, showing roads, rivers, railways and houses. A camera could easily be devised to take a number of different plates automatically, and by drawing in the string, or steering to one side or other, a complete survey of a large district might be effected. Its position as regards the ground would easily be found by cross bearings or otherwise.

In the same way an explosive bomb or shell could be carried up and caused to float over the enemy's head, and be discharged by time fuze, electric wire, or otherwise. The most powerful explosives could be gently lifted up, and thus a terrible engine of war contrived, so simple that it could be carried by one man, yet more destructive than the most powerful artillery. So long as a point more or less to windward of the enemy could be gained, and a sufficiency of wind existed, this terrible bird of prey might hover over the heads of an enemy ; and even if in practice the destructive results were not so great as we might expect, undoubtedly those below would feel somewhat anxious, perhaps experiencing feelings somewhat akin to those of partridges under similar circumstances. Lieut. Baden-Powell stated he had tested the principle on a small scale, using a bunch of grass (weighing 1 lb.) as a dummy torpedo, to be released by a time fuze, hung from a kite with 500 yards of string. It worked very well, and he could even answer for the moral effect produced, as an innocent stranger happened to be passing just underneath the kite when the fatal fuze did its (would-be) deadly work.

Last year, having come to the conclusion that a kite of 500 square feet ought to be sufficient to raise a man in a fresh breeze, Lieut. Baden-Powell had a kite of that size constructed, and found his calculations accurate and expectations satisfied by seeing the junior subaltern lifted off the ground. The object of raising a man would usually be for purposes of observation, working the kite apparatus in the same way as a captive balloon. A kite apparatus which could take up a man would possess many advantages over a captive balloon.

Since an unlimited length of line can be carried by a series of kites, this principle at once suggests itself as a means of communicating with a besieged place. There seems no reason why ten or more miles of telegraph wire should not be thus supported at 1,000 feet or so in the air. All that would be necessary would be to start the kites from some point well to windward, the first kite carrying a weighted line which could be released by a time fuze, and the desired length of kite-supported wire paid out. When the first kite was over the besieged place you would wait till the time fuze had burnt out, and then "drop them a line."

A kite might be the means of raising an electric search-light, which could be directed by several cords. It might also be used for holding up an illumination apparatus for working parties at night. Another simple contrivance might prove of great value in savage warfare; namely, the hanging of a torch on the end of a wire from the kite, by means of which native houses or patches of scrub, etc., occupied by the enemy could be set on fire.

A kite, especially one fitted with guiding lines, might prove a useful means of conveying letters, etc., from one place to another, especially across rivers or other obstacles ; such a kite might even be the means of supplying ammunition to the troops in the firing line, or in any detached post. There are also many other minor uses to which kites might be put—getting ropes across rivers for bridging purposes, raising flags to show the position of camps, hospitals, etc., or even drawing transport wagons when other means had failed.

At sea, kites should prove even of more use than on land. The wind there is usually more steady, and during calm weather a steamer could tow a kite beautifully. As an elevated post for looking out for enemy's ships they should prove most valuable, and for piloting the vessel in unknown waters another peculiar advantage comes in, for an observer, say, 1000 feet up in the air can distinguish objects at a considerable distance beneath the surface of the sea. Count Orloff found that from a captive balloon 1300 feet high over the Baltic Sea, rocks and sand were clearly defined to a depth of 20 to 23 feet.

For signaling, for aërial torpedoes, for carrying messages between ships, they ought to be useful, while for boat sailing dirigible kites should prove most efficient ; there would be no limit to the amount of canvas carried, the boat need not heel over at all, and the wind above is always stronger than below.

SHIPS OF WAR.

ENGLAND.

LAUNCH OF H. M. S. TERRIBLE.

[*The Steamship*, *June*.]

On the 27th of May, H. M. S. Terrible, described as the largest and most powerful cruiser ever built for any nation, was successfully launched by Messrs. James & George Thompson, Limited, from their shipbuilding yard at Clydebank. The keel of the vessel was laid only fourteen months ago, and the builders after the launch were warmly complimented by Mr. Dunn, the Chief Constructor of the Admiralty, upon the expeditious manner in which the work had been carried out. The Terrible shows a decided advance on her type of vessel. Her length over all is 538 feet, and between perpendiculars 500 ft., being 128 ft. more than the Blake or Blenheim, hitherto the largest vessels of the kind in the British Navy. Her breadth, 71 ft., is 6 ft. greater, and her displacement at the load draught of 27 ft. is 14,250 tons, compared with about 9000 tons for the two other vessels mentioned. She is double bottomed, and the hull is divided into no fewer than 236 water-tight compartments. In lieu of the belt of side armor, protection to the machinery and magazines and other vital portions of the ship is afforded by a strong steel arched deck, the crown of which at the center is 3½ ft. above the water-line, while at the sides the edges of the deck are 7 ft. below water level. Additional protection is derived from coal bunkers extending for the length of the machinery above the protective deck, forming, when filled, a solid belt of coal 19 ft. in thickness. The steel skin of the vessel is sheathed outside with teak planks, and a further sheathing of copper will be added after the vessel is handed over to the government authorities. A special feature of the vessel is her speed, and consequently the space devoted to machinery is very large, amounting in total to about half the length of the vessel. On trial she is expected to give 22 knots, while an average continuous sea steaming of 20 is looked for. To attain this speed the vessel is fitted with forty-eight Belleville boilers and two sets of engines of 25,000 combined horse-power. The engines are of the vertical inverted triple expansion type, each engine having four cylinders. Space is provided in the bunkers for over 3000 tons of coal. She will have four funnels. There are in the vessel six decks—the platform deck lowest of all, then the orlop deck, the protective deck, the main deck, the upper deck, and the boat deck. The platform deck, being below the protective deck, is utilized for the stowage of ammunition and torpedoes, and also the steering gear and other works essential to the fighting efficiency of the ship. Her armament will consist of two 22-ton breech-loading guns, twelve 6-in. quick-firing guns, eighteen 12-pounder quick-firing guns, and a number of smaller quick-firing and machine guns, besides four torpedo-tubes. The last mentioned are below the protective deck, and the torpedoes being discharged below water prevents the danger of their being exploded by the enemy's fire. A feature of importance is the protection afforded to the crews of the 6-in. quick-firing guns. Each of the twelve guns is mounted in an armored casemate, which is of sufficient size to contain the gun's carriage and the whole of the crew; and the ammunition is passed into the casemate from below through an armored tube. The vessel will carry officers and men to the number of about 900.

JAPAN.

THE FUJI YAMA.

[*The Steamship, June.*]

The following particulars in reference to war vessels now under construction in this country to the order of the Government of Japan are worth notice. As far back as 1883 a first enquiry was made in this country, through Admiral Ito, the commander of the Japanese fleet in the late war with China, for the construction of two powerful armor-clads of an improved Collingwood type, limited, however, to a displacement tonnage of about 8000 tons. It being found difficult to improve upon this type of vessel with 1500 tons less weight, the limiting tonnage was increased to 10,500 tons, or equal to a vessel of Centurion type; but the proposed new warships being required to carry a heavier armament than the Centurion, the displacement was eventually increased to

12,450 tons, the vessel to be of the Royal Sovereign type. A commission was then appointed, composed of two naval officers—Captain Kitura Yendo, naval attaché in London, and Lieutenant Yamanoutche—together with Commanders Myabara and Takayama, of the constructive department, who visited the most important shipbuilding establishments on the Continent and in America, and from their reports it was at length decided to place the order for the construction of both vessels in this country—one with the Thames Ironworks and Shipbuilding Company, and the second with Messrs. Armstrong, Mitchell & Co., of Newcastle-on-Tyne. As the two vessels are to be sister ships, the following particulars of the one now under construction by the Thames Ironworks Company, to be named the Fuji Yama, after a celebrated mountain in Japan, will apply to both. The length between perpendiculars is 374 ft., the breadth 73 ft., and the displacement 12,450 tons, giving a mean draught of water of 26 ft. 6 in., at which draught the coal carried is 700 tons, bunker capacity, however, being provided for 1200 tons. The armor belt, which is of Harveyized steel plate, the hardening of which has been greatly improved upon in this country by the firms Messrs. Cammel & Co. and Messrs. Vickers & Co., who provide the armor for these vessels, which extends for 226 ft. in length, is 18 in. thick in way of machinery and boiler spaces, and 16 in. at ends. Each vessel has two barbettes, plated with 14-in. armor, and standing upon the steel armor deck, which extends from stem to stern, and is 2½ in. thick. A screen of 6-in. armor runs across the main and lower decks to protect the guns from a raking fire, and the whole of the sides, for the length of the armor belt between belt deck and main deck, is protected by 4-in. armor on a teak backing of 2 in. The armament of each, the whole of which is to be supplied by Messrs. Armstrong, Mitchell & Co., comprises two 12-in. breech loading guns in each barbette; ten 6-in. quick-firing guns, of which four are in casemates; twenty 3-pounder and four 2½-pounder Hotchkiss quick-firing guns; together with five torpedo ejectors, one above water and four below. There are to be two military masts, with tops, to each vessel, and five search lights, and throughout they are to be internally lighted by electricity. The propelling machinery of the Fuji Yama and her sister ship is now under construction by Messrs. Humphreys, Tennant & Co., of Deptford, and will consist of twin-screw three cylinder triple-expansion engines, designed to develop 14,000 indicated horse-power with moderate forced draught. The boilers for supplying steam will be ten in number, of the four furnaced cylindrical type, worked at a pressure of 155 lbs. per square inch. Notwithstanding the great pressure which was exerted in Tokio to obtain permission for other firms to compete for the construction of the Fuji Yama and her consort, the two above-mentioned were the only ones invited to tender for these vessels. The construction of the Fuji Yama is being rapidly proceeded with. The side armor is partly rolled, and will be delivered shortly at the works. The original time for completing was four years, but now the time has been reduced by arrangement to three years. The vessel has been designed by Mr. Geo. C. Mackrow, naval architect to the Thames Ironworks.

BOOK NOTICE.

NAPOLEON BONAPARTE'S FIRST CAMPAIGN, WITH COMMENTS. By Herbert H. Sargent, First Lieutenant Second Cavalry, United States Army.

Lieutenant Sargent makes no apology for presenting anew a much written subject, but, when the book is read, one will truly admit that no apology is needed. Confining himself admirably to the strategy of the campaign, the author treats each successive stage in a separate chapter, closing each chapter with carefully considered comments, and completing his task with a final chapter of general comments on the whole. The freedom from collateral detail and the vigor of this strategic narrative, combined with simple commentaries applying to it the principles of the art of war, cannot fail to convert its most casual reader into an interested student.

The maps, two in number, are poorly drawn. The final chapter of general comments could be advantageously condensed. The author makes occasional allusions to "the French eagles" and "the eagles of Napoleon," overlooking the fact that the eagle as an emblematic bird was unknown to France and unthought of by Napoleon until several years later. These are trivial shortcomings, and the general reader, as well as the military student, will lay aside this book feeling glad that he has read it, and with the reassurance that the officers of our army, even when stationed at isolated posts where libraries are meagre and frontier life is arduous, are carefully studying the campaigns of the great military masters. J. M. E.

BIBLIOGRAPHIC NOTES.

AMERICAN.

ARMY AND NAVY REGISTER.

The Infantry Drill Regulations. The Manual of Arms adapted to the Magazine Rifle Caliber .30.

To insure uniformity of practice in the manual of arms for the new Army rifle, the War Department has made many modifications in manuals formerly used. The new manual is to govern the Army. It will be of great interest to national guardsmen, as the different states will also use the work. The *Army and Navy Register*, of Washington, D. C., has issued the manual in pamphlet form, the price of which is 15 cents per copy. A recent law prohibits the War Department from printing over 1000 copies of any document, which will limit their distribution to only a few in the Army.

THE AMERICAN ENGINEER AND RAILROAD JOURNAL.

June, 1895. Some Facts Relating to Certain Types of Water-Tube Boilers. The Curve of Least Resistance in Water and in Air.

July. Method of Taking Cost Test and Chilling Points of Oils, and Other Liquids. The Proposed French Captive Balloon. High Balloon Ascensions.

August. Tubulous Boilers in the French Navy. The Economy of Steam Jackets and Superheated Steam. Third-Class Torpedo Boat for U. S. Cruiser Maine. The Proximate Analysis of Coal. The Fuse for the Pneumatic Dynamite Guns (illustrated). Aeronautics; Speed in Migratory Flight of Birds; Velocity of Air Currents.

The author measures cloud velocities, determining the position of a cloud by suitable theodolites at the end of a 1178 meter base line. He then calculates the mean cloud velocities, and from these latter states that for high altitudes (above 200 meters), in the same season, the increase of velocity is regular and uniform; that is, is proportional to the increase in height.

CASSIER'S MAGAZINE.

Niagara Power Number. Tesla Motors in a Great Manufacturing Establishment. The Use of the Niagara Water Power. Mechanical Energy and Industrial Progress, by W. C. Unwin.

Distribution of the Electrical Energy from the Niagara Falls, by S. Dana Greene, Electrical Engineer.

A number of other articles bearing upon the Niagara Falls and their power; articles, historical and scientific, beautifully illustrated, accompany those mentioned. The number, devoting two hundred and twelve pages to its subject, will have to be seen to be appreciated.

June. The Care of Steel Ships, by Philip Hichborn, Chief Constructor U. S. N.

The author advocates the sheathing of ships' bottoms.

Some Recent Machine Tools. The Maximum Possible Efficiency of Galvanic Batteries. Philip Hichborn (a short biographical sketch, by Robert Gregg Skerrett). Electricity for Marine Propulsion. Solid Force Transmission.

IRON AGE.

June 13, 1895. Centrifugal Pumps for United States Dry Dock.

June 20. Tests of Corn Cellulose. Test of Maxim Machine Gun.

The Maxim rapid-fire single barrel machine rifle for infantry use, which was the type used in these tests, has a caliber of 0.303. The cartridges are 2.8 inches in length. The range of the gun is 3200 yards. Smokeless powder is used, giving a muzzle velocity of 1850 feet per second. The gun weighs 25 pounds when placed on its iron stand, ready for action. When taken apart and packed with ammunition and extra equipment, its total weight is 45 pounds; so that it can be readily carried by one man. Its average capacity is 500 shots a minute.

The first test was one of 50 rounds, which were fired in 5⅘ seconds. The time for unloading the gun from the knapsack to the time when the last shot was fired was 57¼ seconds. The next test was one of time. A shot was fired, the gun barrel removed, another barrel taken from the knapsack and inserted, loaded and fired within one minute and 12 seconds.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

July, 1895. Discipline. An Antiquated Artillery Organization. Martial Law and Social Order. Recruiting and Training of the Company. Our Artillery in the Mexican War. A Technical Criticism of Our Infantry Drill Book. Reprints and Translations.

JOURNAL OF THE UNITED STATES ARTILLERY.

April, 1895. The Resistance of the Air to the Motion of Projectiles as Influenced by the Shape of the Head, by Capt. Jas. M. Ingalls, First Artillery, U. S. A. Trained Artillery for the Defense of Sea-Coast Forts. Range and Position Finding. The Uses of the Artillery Fire Game. Coast Artillery Fire Instruction.

JOURNAL OF THE FRANKLIN INSTITUTE.

June, 1895. The Nicaragua Canal. Lightning Arresters and Why they Sometimes Fail.

July. An Apparatus for Experimenting with the Laws of Flexure of Beams. The Theory of the Air Lift Pump. Cellulose Protection for War Vessels and for the Merchant Marine. Reasons for Predicting the Existence of Argon.

SCHOOL OF MINES QUARTERLY.

April, 1895. Modern Calorimeters and their Use. Argon. Chloride of Silver as an Anti-Friction Metal.

FOREIGN.

ENGINEER.

Volume LXXIX., No. 2053, May 3, 1895. The United States Naval Gun Foundry at Washington, D. C. H. M. S. Royal Arthur.

May 10. The Story of Ship-Building on the Tyne. The United States Naval Gun Factory at Washington D. C. (concluded).

May 17. The Stability of French Armored Ships. Launch of a New First-Class Battleship (the Renown).

May 24. Torpedo-Boat Destroyers. H. M. S. Terrible. Face Hardened Armor, by Lt. A. A. Ackerman, U. S. Navy.

A review of the article published in No. 73, Proceedings U. S. Naval Institute.

May 31. The Launch of H. M. S. Terrible. Armor Plate Tests.

June 7. British Fuses for Modern Guns. Instability in Ships of War. Coal Consumption on Torpedo-Boats.

A correspondent of the *Glasgow Herald* states that the torpedo-boat destroyer built by Messrs. Thornycroft on a three hours' run maintained a speed of 27.97 knots—practically 28 knots—or for the whole time 84 nautical miles; and burned in her three water-tube boilers 17¼ tons of coal. The rate of combustion is 68 lbs. of coal per square foot of grate area per hour, although in some trials it has reached 79 lbs.; but then the power per square foot of grate area is very high, 24 indicated horse-power. The boats of this class carry 60 tons of fuel at a pinch, and this would enable them to go at full speed for a period of over nine hours, during which they would travel fully 250 nautical miles. The coal consumption is equal to 4 cwt. per sea mile; that is to say, during the 2 min. 9 sec. taken to a sea mile 4 cwt. of coal are burned. A ton of coal, therefore, takes the boat five sea miles. But it would only be on a rush that such speed would be maintained. Now, other tests have been made at about half the speed—13 knots—and here, instead of five miles, the ton of coal carried the destroyer for a distance of about 38 nautical miles, so that the total distance at 13 knots with the 60 tons of coal would be nearly 2000 miles. This shows the great cost of doubling the speed. The coal per horse-power at 13 knots was 1.61 lbs.

JUNE 14. The Baltic Canal.

JUNE 21. The Cost of Warships (with table in some detail). On Coupling Boilers of Different Systems.

JUNE 28. The Cost of Warships (concluded). Small-Arm Ammunition. On Water-Tube Boilers.

JULY 5. A New Departure in Steam Engine Economy. New Method of Fitting Shell and Deck Plating in Ships.

ENGINEERING.

VOLUME LIX., No. 1528, APRIL 12, 1895. The New Nordenfelt Guns (concluded). The Institution of Naval Architects. An Aluminum Torpedo-Boat. H. M. Torpedo-Boat Destroyer Ardent. The Propelling Machinery of H. M. S. Magnificent. Our Battleships, by Sir William White, K. C. B. On Solid Stream Forms, and the Depth of Water Necessary to Avoid Abnormal Resistance of Ships, by Naval Constructor D. W. Taylor. Induced Draught.

APRIL 19. The Institution of Naval Architects. Naval Works. On the Vibration of Ships and Engines. On Vibrations of a Higher Order in Steamers, and on Torsional Vibrations.

APRIL 26. The New British Cruisers. On a Method of Preventing Vibrations in Marine Engines.

MAY 3. The Institution of Mechanical Engineers. Quadruple Flashing Dioptric Apparatus. Water-Tube Boilers in Parliament.

MAY 10. The Economics of Coal. Heat Engines. Electric Welding for Repairs.

MAY 17. Japanese Shipping. The Development of Naval Ordnance.

MAY 24. The New British Cruiser Terrible. The Borchardt Repeating Pistol. Torpedo-Boat Destroyers.

MAY 31. The New British Cruiser Terrible (continued).

JUNE 7. Gunnery Trials of the Infanta Maria Teresa.

JUNE 14. The Institution of Naval Architects (Paris Meeting).

At this meeting was read a paper entitled *M G* Meter. In it the author, Mr. Archibald Denny, described an instrument which had been devised for the use of masters of vessels, so that they might obtain the metacentric height of a vessel. It consisted essentially of a spirit level pivoted at one end, and adjusted at the other by means of a micrometer screw. By the aid of a diagram the value *M G* is ascertained in a way set forth by the author.

JUNE 21. The Amplitude of Rolling on a Non-Synchronous Wave, by Emile Bertin. On Wood and Copper Sheathing for Steel Ships, by Sir William White, K. C. B.

JUNE 28. The New British Cruiser Terrible (concluded). On Wood and Copper, etc. (concluded).

JULY 5. The Measurement of Pressures by the Crusher Gauge.

In a recent communication to the Royal Society, Messrs. W. Kellner and W. H. Deering describe a series of experiments on crusher gauges. The gauges in question were of the usual form, and each was constructed of a small cylinder of copper .5 in. long and .326 in. in diameter, inclosed in a small steel cylinder, fitted with a steel ram .461 in. in diameter. One end of this ram rested on the copper rod, whilst the other was exposed to the pressure to be measured. These pressures were generated by firing cordite in closed explosive vessels of steel, having a capacity of about 120 cubic centimetres. The vessels were closed by screw stoppers, which were about 4 in. long, and were drilled axially with a ¼ in. hole. The mouth of this hole was closed by a hardened steel ball ½ in. in diameter, which could be loaded with any desired weight, thus forming a valve. By means of this device an independent measure of the pressure inside the vessel could be obtained, since, if the valve did not lift, the pressure inside must have been lower than that corresponding to the weight on the ball. The effective area of this valve was very carefully measured. By planing off a short length at the top of the plug, a new seat could be obtained for the valve when required. The weights of cordite fired were increased by short steps till a point was reached at which the gases resulting from the explosion were blown out, and the pressure thus obtained was compared with the indications of the crusher gauge. The general result arrived at was that the pressure, as estimated by the crusher gauge, was invariably too low, being about 11 per cent. wrong at pressures of 6 tons per square inch, 9 per cent. wrong at pressures of 13 tons per square inch, and 11 per cent. wrong at 16 tons per square inch.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

MAY, 1895. Gold Medal Prize Essay. Lessons to be Derived from the Operations of Landing an Expeditionary Force on an Enemy's Coast in Past Wars. A Few Practical Hints on the Working and Use of Maxim Guns. Field Artillery Fire and Okehampton Experiences.

JUNE. The Antarctic Expedition from a Naval Point of View.

JULY. Landing of Expeditionary Forces On Ship Ventilation as a Department of Naval Hygiene. Economical Army Reform, by Captain F. N. Maude, late R. E.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

MAY, 1895. Proposed Slide Rules for Calculating Battery Commanders' Corrections.

The corrections referred to are those necessitated by the movement of the target after the range has been found.

Co-operation Between Guns and Cavalry. Diary of Lieutenant W. Swabey, R. H. A., in the Peninsula.

June. Terrestrial Refraction and Mirage. Diary, etc. (continued).

STEAMSHIP.

June, 1895. First-Class Battleship Fuji Yama. Launch of H. M. S. Terrible. Corrosion of Boilers and Steamships. Launch of First-Class Battleship Renown.

July. Hydraulic Machine Tools. Cost of H. M. Vessels.

UNITED SERVICE GAZETTE.

No. 3253, May 11, 1895. The Genesis of English Naval Power. The Advance in the Organization and Efficiency of the Royal Naval Reserve.

May 18. Torpedo-Boat Destroyers. Ship Ventilation. Physical Training in the American Army, I.

May 25. War Kites. The Times and the War Office, III.

June 1. Physical Training in the American Army, II.

June 8. The Objects of the Navy League. Physical Training in the American Army, III. The Training of Naval Acting Sub-Lieutenants.

June 15. Commerce Protection in War Time. The Effect of War on Our Mercantile Marine. Moral Effect in War.

June 22. Military Reform. The Imminence of War.
A synopsis and endorsement of Assistant Naval Constructor Hobson's article on the "Situation and Outlook in Europe," in No. 74, Proceedings U. S. Naval Institute.

June 29. Water-Tube Boilers. Parliament and the Defense of the Country. Our Own and Foreign Warships.

July 6. The Armament of Warships. J. H. G.

LE MONITEUR DE LA FLOTTE.

No. 15, April 13, 1895. The Law in Regard to Promotion in the Navy. Something More About Running Lights.

No. 16, April 20. Remarks on the Law of Promotion.

No. 17, April 27. One Point in History. Voyage of the President of the Republic.

No. 18, May 4. The Mediterranean Postal Service. A Magnetic Map of the Globe. The Extraparliamentary Naval Committee.

No. 19, May 11. Speed Trials. The Extraparliamentary Naval Committee.

No. 20, May 18. The Working by Hand of Heavy Caliber Guns.

No. 21, May 25. Armor and Projectiles. Loss of the Torpedo-Boat 20. The Accident on Board the Amiral Duperré.

No. 22, June 1. About the Combat of Ya-Lu.

A brief summary of facts that were demonstrated in this memorable action.

Nos. 23 and 24, June 8 and 15. The Congress of Naval Architects. What About Cellulose? The Navy Estimate for 1896.

No. 25, June 22 and June 29. At Kiel. The Extraparliamentary Naval Committee. The Naval Manœuvres of 1895.

No. 27, July 6. Privateer Cruisers (commerce destroyers).

REVUE DU CERCLE MILITAIRE.

Nos. 14 and 15, April 6 and 13, 1895. The English Military Recruiting System. Madagascar. The 13th Army Corps in the War of 1870 (map). The Spanish in Cuba.

Nos. 16 and 17, April 20 and 27. The Folding Bicycle in the Army. English Recruiting (continued). The 13th Army Corps, etc.

No. 18, May 4. Simple Chat on Aërial Navigation (see No. 17). Instructions of the Emperor of China to his Army.

No. 19, May 11. A Comparative Study of Service Small Arms.

No. 20, May 18. The Artillery Combined with the Other Arms.

No. 21, May 25. The Meldereiters of the German Army. The Artillery Combined with the Other Arms (continued). The Pneumatic Gun in the United States.

No. 22, June 1. The Dutch Colonial Troops; Notes Relative to the Dutch-Indian Army. The Artillery Combined, etc. The War Budget of 1896.

No. 23, June 8. The Daily Ration of the Italian Sailor. The Dutch Colonial Troops, etc.

No. 24 and 25, June 15 and 22. The Navy Appropriations for 1896. The Preliminaries in the Madagascar Expedition. The Dutch Colonial Troops. The Artillery Combined with the Other Arms (end).

No. 26, June 29. To the North Pole in a Balloon. The Dutch Colonial Troops (continued).

REVUE MARITIME ET COLONIALE.

March, 1895. The Volta in China and Tonkin (1883-1885) (ended). Naval Warfare (an analysis of the work of Rear-Admiral Colomb). A Note on the Attack on the Brazilian Armored Battleship Aquidaban by the Government Torpedo-Boats, on the Night of the 15th of April, 1894. Description and Working of the Hydraulic Apparatus of the Gun of 340 mm., Model 1887. A Report on the Process to be Employed in Discovering Fraud in Table Oil and Oils Used in Manufactures.

April. Naval Warfare (an analysis of the work of Rear-Admiral Colomb). Description and Working of the Hydraulic Apparatus of the Gun of 340 mm., Model 1887. Geometry of Diagrams (continued).

SOCIÉTÉ DES INGÉNIEURS CIVILS.

March, 1895. Congress of Naval Engineers at Chicago. Analysis of the Statistics of Coal Mines in France. Seisms and Volcanoes.

April. The Electric Cranes of the Port of Havre. A Note on the Mishap of the Steamer Gascogne. Public Aids in France and Other Countries.

May. Establishment of Pensions in Favor of Miners by Mining Companies.

LE YACHT.

No. 891, April 6, 1895. The Colonial Troops and the Navy Ordnance Department.

No. 892, April 13. The Navy in the Senate. The Protected Cruiser K. and K. Maria-Theresa.

No. 893, April 20. The Wei-Hai-Wei War Operations. The German Armored Battleship Wörth.

No. 894, April 27. The Peace Between China and Japan. The President of the French Republic at Havre. Admiral Galaches' System of Running Lights. The Trials of the Friant.

No. 895, May 4. The New Italian Naval Constructions.

On the stocks at Venice is the armored battleship Ammiraglio Saint-Bon; at Castellamare the Emanuele Filiberte; these are sister ships. Two types of armored cruisers are being built: to the first belong the Carlo-Alberto at Spezia, and Vittor Pisani at Castellamare. To the second type, the Garibaldi at the shipyards of Ausaldo at Sestri Ponente, and the Varese at the Orlando ship yards at Leghorn. The last two are somewhat larger than the first. Besides two protected cruisers, the Puglia at Tarenta, and the Elba at Castellamare, Italy has in construction several vessels of inferior rate.

The Third-Class Japanese Cruiser Suma, Built at the Government Docks at Yokosuka.

No. 896, May 11. The English Navy. The Institute of Naval Architects. The Multitubular Boiler in the House of Commons (E. Weyl). The New Constructions in Italy. The German Armored Coast Guard Vessel Siegfried.

No. 897, May 18. Creation of a Bureau Technique in the Navy. Russian Cruisers Building at Havre.

REVISTA TECNOLŌGICO INDUSTRIAL.

April, 1895. The Installation of Transmission Power by Electricity at the Niagara Falls. Acetilene: Its Commercial Manufacture by Electricity; Its Adaptation to Lighting and the Carburation of Coal Gas.

May. Improvements in the Manufacture of Bone Gelatine and Glue.

June. Acetilene, etc. Scientific Industrial Excursion of the Association of Industrial Engineers of Barcelona During the Month of June, 1895.

REVISTA MARITIMA BRAZILEIRA.

February, 1895. Autobiography of a Whitehead Torpedo. Reorganization of the Brazilian Navy. The Practice Ship Benjamin Constant. Torpedo-Boat Destroyers.

March and April. Autobiography, etc. Reorganization of the Brazilian Navy. Pyrotechny. Smokeless Powder. Report of Engineer Antonis Perraz of the Brazilian Navy.

BOLETIN DEL CENTRO NAVAL.

Volume XII., January and February, 1895. Brief Historical Notes on Naval Warfare, by Lieut.-Comdr. Silveyra. Steel for Ordnance.

J. L.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

Volume XXIII., No. 3. Sailing Directions for the Cameroon Coast. The Journal of Capt. Scheder, Commanding the Corvette Bussard. Circumnavigation of the Island of New Hanover. Remarks on the Description of the Coast of Annam. The Gale of Dec. 22, 1894. The Ex-Meridian Treated as a Problem in Dynamics, H. B. Goodwin, M. A. Hygienic Meteorology. Bottle-Posts. Receipt of Meteorologic Journals at the German Naval Observatory in February, 1895.

No. 4. From Honolulu to Yokohama. Cruising among the Samoan Islands. Failure to locate Colonia Shoal; Approaching Samana Bay (sailing directions). Hydrographic Conditions of Esmeralda River and the Anchorages at its Mouth. Currents along the East Coast of Africa, between Cape Guardafui and Zanzibar, during the Southwest Monsoons. Wind and Weather in the Antarctic Ocean South of Cape Horn, 1893 to 1894. On the Computation of Nautical Astronomical Problems with Four-Place Logarithms. The Coast Climate of Ecuador. Minor Notices: Shoal on Campeche Bank; Yellow Fever at Sea; From Apia to Auckland; Soundings in the Harbor of Newcastle, N. S. W.

No. 5. From Valparaiso to Puerto Montt. Water Temperatures on a Trip from Chefoo to Chemulfo and Back. Experiments on Smoothing the Sea with Soapy Water. A Trip up the Yang Tse Kiang, and a Description of Three Typhoons. Aroe Bay, Sumatra. Report of the German Naval Observatory on Results of Magnetic Observations Along the German Coast, During 1894. Balloon Ascents to the Regions of Cirrus Clouds. Studies on Fog Signals. Transparent Diagrams of the Atmospheric Movements During Cyclones and Anti-Cyclones. Meteorology of Purdy Islands. Notices: A Danish Expedition for Exploring the Waters of Greenland.

No. 6. Cameroon, Sailing Directions. Remarks upon Cameroon, Cape Cross, Whale Bay, Cape Town, Port Natal. Voyage from Rangoon to Rio Janeiro. Experiments with Visibility and Clearness of Vessels' Running Lights, with Particular Attention to the Proper Coloring of the Shades. Studies on Fog Signals. The New Mouth of the Weichsel.

ANTHROPOGEOGRAPHISCHE BEITRÄGE ZUR GEBIRGSKUNDE.

Scientific publication of the "Verein für Erdkunde," of Leipzig.

Volume II. A Study of the Dependence of Thickness of Population Upon Geographical Conditions, with Especial Attention to Altitude Zones and their Boundaries.

CHAP. I. Dependence of the Different Population Percentages in Saxony upon Geographical Surroundings.

CHAP. II. Population Strength in West Central Africa.

CHAPS. III. AND IV. Geographical Studies in the Alps, and Altitude Zones.

CHAP. V. The Regions of Mt. Etna.

DEUTSCHE HEERES ZEITUNG.

NOS. 26, 27 AND 28. Battle Tactics of Infantry as Affected by Modern Weapons (continued).

No. 35, MAY 1, 1895. New Organization of Foot Artillery. Battleship Kaiser to be Flagship of Asiatic Squadron.

No. 36, MAY 4, AND No. 37, MAY 8. Fighting In and About Villages, with Especial Reference to the Battle of Gravelotte St. Privat, Aug. 18, 1870. Assignments of French Vessels to Squadrons.

Nos. 38 AND 39. On the Necessity of Improvement in Marksmanship in the Reserves and Landwehr. Shrapnel Fire of Field Artillery, Present and Future. Loss of the Reina Regente. The Strategic Position of La Maddalena.

No. 40. What Protects Our Sea Commerce?

An appeal to the German public for modern cruisers explains away the mistaken economy of the Reichstag in cutting out appropriations for increase of the Navy.

Shrapnel Fire of Field Artillery, Present and Future (concluded). Russia's Newly Proposed Ships. The Army and Navy of Turkey.

No. 41. Armor Plates.

Notes on some armor plates exhibited at Antwerp.

No. 42. The Italian Campaign in Erythraea. Developing Marksmanship in French Army. Electric Target.

No. 43. New Organization of Russian Engineer Troops. New English War Ships. Launch of the Suma Kan, Japanese Cruiser.

No. 44. Observations of an English Officer on the "Lawa" of the Cossacks.

No. 45. Launch of the Renown. The Present Fleet of Japan.

No. 47. Penetration of Modern Rifles.

English experiments with the Lee-Metford, Mannlicher and Martini-Henry rifles.

No. 48. The Right to Close Neutral Water Highways.

No. 49. Aden and the Neutrality of the Suez Canal.

No. 52. Launch of the Terrible.

No. 53. Artillery in Connection with the Other Service Arms. Use of Kites for Military Purposes. Description of the Bouvines.

No. 54. New Russian War Ships. New English Ships Algerine and Spitfire.

No. 58. A Comparison of the Fleets at Kiel.

No. 59. The Battle of the Yalu.

GEOGRAPHISCHE ZEITSCHRIFT.

A Geographic Periodical, published by Alfred Hutner, of Leipsic.

VOLUME I., No. 1. Contents: Geographic Investigation and Education. The Peace of Simonoseki in its Geographical Relations. Effects of Climatic Changes upon the Harvests and Price of Grain in Europe. The 9th Geographic Reunion in Bremen. Geographic News.

MILITÄR WOCHENBLATT.

Nos. 48–50, JUNE 5, 1895. The Italian Cruiser Giuseppi Garibaldi. The French Colonial Army. Reorganization of Bulgarian Army.

Nos. 51, 52 AND 53. Our Military Academy. On the Decisive Battles on the Saale. French Cavalry.

Nos. 56–58. Two Years in the Chilean Service. Launch of the Renown. Remarks upon the New Regulations for Infantry Attack.

No. 59. Studies on Field Duty. The Present Status of the American Navy. Launch of the Terrible.

No. 60. Timely Changes in Rifle-Practice for Infantry.

No. 61. Railway Protection and Railroad Warfare. Pigeon Service in Italy. Watkins Position Finders.

Nos. 66–68. Studies on Field Duties. A Contribution on the Subject of Rifle Practice.

Nos. 69–70. On the Mobility of Field Artillery. Annual Report on the Target Firing in France for 1864.

No. 71. The French Naval Programme for 1896.

BEIHEFT ZUM MILITÄR WOCHENBLATT.

No. 3, 1895. The Development of Our Infantry Tactics Since Our Last Wars. Judging the Effects of, and Preparing Problems for Firing Discipline of Infantry and Field Artillery.

No. 4. The Disposition of the Reserves in the Battle of Bionville Mars la Tour with Especial Consideration of the 5th Infantry Division, by Lieutenant General v. Wodtke. My Experiences in the Battle of Bionville Mars la Tour, by Colonel L. Schaumann.

No. 5. Commissary Arrangements for Sustenance of the Russian Army in the Danubian Campaigns of 1877–78.

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H. G. D.

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Lieutenant J. H. GLENNON, U. S. N. Lieutenant H. G. DRESEL, U. S. N.
Lieutenant J. M. ELLICOTT, U. S. N. Professor JULES LEROUX.

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OF THE

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CONTENTS.

NOTICE.

Owing to impracticability of sending out more than a very limited number of, if any, advance copies of the articles, in the various numbers, and thereby reaching all the members, such appropriate discussions as may be contributed by members after the issue of a number will be printed in the succeeding number. In the case of certain leading articles a limited number of advance copies will be sent out in addition, as may be requested by authors, as hitherto.

J. H. Glennon,
Secretary and Treasurer.

NOTICE.

Through an error made by the printer after the final reading of the proof, the words "Honorably Mentioned" were omitted from the heading of the essay on the Battle of the Yalu in No. 75.

The chart referred to, in this essay, as published by the Intelligence Office (pp. 480 and 510 of No. 75), is not from that Office, being in fact H. O. chart 1443.

J. H. Glennon,
Secretary and Treasurer.

THE PROCEEDINGS

OF THE

UNITED STATES NAVAL INSTITUTE.

Vol. XXI., No. 4. 1895. Whole No. 76.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

AS TO NAVY-YARDS AND THEIR DEFENSE.*

By Rear-Admiral S. B. Luce, U. S. Navy, President of the U. S. Naval Institute.

On the formation of the government under the constitution of 1789 there were no navy-yards. The public armed vessels that had figured in the Revolutionary war had been built at private shipyards. Indeed, from the time of the sale in Philadelphia in June, 1785, of the Alliance, the last ship of the Revolutionary period, to the launching of the United States (44), at the same port in May, 1797, an interval of twelve years, the country was without a navy.

The passage of the act of March 27, 1794, authorizing the construction of six frigates, was the first step towards the formation of the second, or present navy.

In regard to the construction of these frigates, the Secretary of War (who at that time administered the affairs of the navy) submitted to the House of Representatives a communication under

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* From notes taken in the course of preparation of "Report of the Commission on Navy-yards, December 1, 1883."

date of December 29, 1794, in which he states that "the building of the ships has been directed in the several ports of the Union, in order, as well to distribute the advantages arising from the operation, as to ascertain at what places they can be executed to the greatest advantage, to wit: One thirty-six at Portsmouth, N. H.; one forty-four at Boston; one forty-four at New York; one forty-four at Philadelphia; one thirty-six at Baltimore, and one forty-four at Norfolk."

The sites on which these vessels were built belonged to private individuals.

Two years after (January 11, 1797), in a letter addressed to the chairman of the House "Committee for inquiring into the state of Naval Equipments," etc, etc., he states that "if Congress perceive advantages in the extension of their marine . . . it will be proper that authority be given to purchase a site for a navy-yard." In compliance with this recommendation the House committee on Naval Affairs on January 25 reported "as their opinion that a sum of money be appropriated for the purpose of purchasing and fitting up a naval yard." This recommendation, however, was not adopted by Congress.

In January, 1798, a committee of the House was appointed "to inquire into the expenditures of the moneys appropriated for a naval armament, and also into the causes of the delay in completing the same." In answer to the inquiries of this committee the Secretary justifies the wisdom of his predecessor in having all the ships built at the same time, and in different places, and adds: "The great delay that has occurred in the present undertaking must always be more or less experienced when heavy ships of war are required to be suddenly built, and the Government not previously possessed of the necessary materials. It is certainly an unfit time to look for these and prepare a navy-yard when the ships are required for actual service. . . . Do not these circumstances point to the expediency of legislative provisions commensurate to so important an object?"

Again on January 17, 1799, a committee of the House recommended that "for the safekeeping and careening of ships-of-war of the United States a dock or docks should be established in one or more places in the United States." But Congress again failed to adopt the recommendation.

Under date of April 25, 1800, the Secretary of the Navy (a department of the navy having, in the meantime, been authorized by law) submitted for the consideration of the President a very strong appeal in favor of the purchase of sites for navy-yards. "No express provision," he remarks, "was made by Congress for establishing navy-yards for building the first six frigates directed by law. But as vessels so large cannot be built without first erecting wharves, or extending wharves before erected, both these things were done, and in every instance on private property; so that the public have now little or no advantage from the expenditure of sums to a considerable amount." Then follows a forcible argument showing the wasteful extravagance of the prevailing system. "In this view of the subject," he continues, "and believing that it is the truest economy to provide at once permanent yards, which shall be the public property, and which will always be worth to the public the money expended thereon, instead of pursuing the system at first adopted, which, with the experience before us, can only be justified on the ground that the ships now ordered are the last to be built by the United States, the Secretary of the Navy has had but little difficulty in making up his opinion that the proper course to be pursued is to make the building yards at Norfolk, Washington, New York and Portsmouth public property, and to commence them on a scale as if they were meant to be permanent; and also the building yards at Philadelphia and at Boston, notwithstanding the high prices which must be given for the ground."

Accompanying this paper is an elaborate report by Mr. Joshua Humphreys, Naval Constructor, and the designer of the new frigates—those of the Constitution class—on the various sites proposed for navy-yards.

In a letter from the Secretary of the Navy to the House Naval Committee on the naval establishment and its expenses, under date of January 12, 1801, after quoting the act authorizing the construction of the seventy-fours, he says: "Ground has been purchased at Portsmouth, N. H., Charlestown (near Boston), Philadelphia, Washington and Norfolk, and measures have been taken to procure ground at New York for capacious building and dockyards, and progress in making and preparing docks for receiving timber, and wharfs for building ships."

As nothing in the acts quoted authorized the purchase of sites for navy-yards, it will be seen that the Executive took the initiative steps for the formation of a permanent naval establishment. This is explained in a communication to the House under date of December 8, 1801. "How far the authority given by the Legislature for procuring and establishing sites for naval purposes has been perfectly understood, and pursued in the execution, admits of some doubt. A statement of the expenses already incurred on that subject shall be laid before you. I have in certain cases suspended or slackened these expenditures, that the Legislature might determine whether so many yards are necessary as have been contemplated." Then follows a statement of

Expenditures on Account of Navy-Yards, Docks and Wharfs, to 1st Oct., 1801, as follows:

Portsmouth, N. H.—Purchase of ground	$5,500	
Improvements	26,304	$31,804
Boston.—Purchase	40,000	
Improvements	3,643	43,643
New York.—Purchase	40,000	
Improvements	1,865	41,865
Philadelphia.—Purchase	37,000	
Improvements	1,636	38,636
Washington.—Purchase	4,000	
Improvements	54,683	58,683
Norfolk.—Purchase	12,000	
Improvements	14,275	26,275
	Total	$240,906

In 1802 a committee of the House to whom was referred "so much of the President's message as related to naval sites" reported that "prior to 4th March, 1801, the sum of $199,030.92 had been expended in purchasing navy-yards and making improvements upon them, *without any law authorizing the purchase, or any appropriation of money either for purchase or improvements.*" But in the body of the report it is stated that "On that day—March 3, 1801—it appears by the act making appropriations for six seventy-four-gun ships, and for *completing navy-yards, docks and wharfs*, the sum of $500,000 was appropriated."

From this it would appear that Congress had finally recognized the existence of the navy-yards by making an appropriation of money for their maintenance. Hence from this date—March 3, 1801—the six navy-yards named may be considered as part of the permanent naval establishment.

Under date of January 20, 1802, the Secretary of the Navy writes to the chairman of the House Naval Committee: "Since I have been in office I have anxiously sought for all possible information respecting the navy-yards, but no satisfactory opinion has yet been formed with regard to the yards *that ought to be sold.* There is reason to believe that the site of the navy-yard at Philadelphia ought to be changed. There is an opinion entertained by some that the site of the yard at Portsmouth is not the best; and doubts have been expressed respecting the proper position of the yard at New York. . . .

"With respect to the contemplated improvements of the navy-yards . . . I have only to remark that from the reduced scale of the proposed appropriation the intended improvements must, in a great degree, be suspended. . . .

"If Congress should deem it necessary to sell any of the present navy-yards, or to purchase other situations, and a committee should be appointed to prepare a bill for such a purpose, I will with pleasure contribute my assistance." Thus early in the history of our navy was the question of the sale of navy-yards brought forward.

The doubts here expressed as to the wisdom of the selection of the several sites were reiterated later on. In his annual report of December 2, 1825, the Secretary of the Navy says that "*The experience of the Department and personal observation during the last year have entirely satisfied me that the greater part, if not the whole, of our navy-yards are badly located.*" The Secretary then proceeds to discuss the difficulties presented by the building arrangements at the navy-yards. "They have," he observes, "been improved by temporary expedients, and the buildings erected and arranged with reference only to existing necessities, and without regard to the future and growing wants of our navy. Many and serious evils have resulted; much public money has been unnecessarily expended, many losses sustained by the change, removal and alteration of the several erections; timber exposed to decay; stores requiring immense labor to deposit and preserve them; a much larger number of hands required to perform the work; unpleasant and sometimes injurious delays in fitting out our vessels. It is a mortifying fact, yet there is no doubt of its truth, that one-third of the money expended at our yards has been lost from this cause. The remedy is manifest, and it is earnestly hoped that means may be provided to apply it. A commission of prudent and intelligent officers should be selected to examine minutely and carefully all our navy-yards, and to make a plan for each, suited to its location and the future wants of the service at it, prescribing the buildings which will be required and the location and character of each building, together with such improvements in the ground and form of the yard as will be most beneficial."

It will be seen from the foregoing that the sites of the six yards named were, with the exception of the one at Washington, determined by a process of "natural selection," as it were. That is to say, that having no public shipyards, the government naturally went to those places for setting up their first ships where ship-building formed one of the industries, and where skilled labor and the materials which entered into ship-building mostly abounded. Thus expediency controlled the selection of the sites of the navy-yards, and expediency has controlled their development.

How irregular soever the manner of doing it, the wisdom of thus early laying the foundation of a permanent naval establishment was soon to be justified. Our extreme weakness, in a military point of view, invited the aggressions which led to the war of 1812. By the superiority of the naval power of Great Britain most of our Atlantic ports were blockaded and a number of our ships-of-war were burnt to prevent them from falling into the hands of the enemy. But however inferior on the ocean, on the lakes we met our adversaries on equal terms. It was there that arose that contest of energy and enterprise in constructing ships out of the "raw material," and skill in fighting them afterwards, that reflected such great credit upon our national marine.

There were three lines of military operations in the north: that near the head of Lake Erie; the one on the Niagara frontier; and the one which had Lake Champlain for its base. On all three lines the successes gained by the American naval forces led to the most important results. As a direct consequence of Perry's victory on Lake Erie, the Northwest was relieved from invasion; Gen. Harrison's army enabled to advance into Canada;

the battle of the Thames fought, Tecumseh killed; the last great Indian combination broken up; and Detroit and the Michigan territory recovered. McDonough's victory on Lake Champlain ended the attempted invasion of northern New York and terminated the campaign of the English forces on that line; while Commodore Chauncey's brilliant successes on Lake Ontario caused the British to evacuate the whole Niagara frontier. The operations of war had therefore introduced new strategic points; and to the six navy-yards, at one time deemed an excessive number, there were added at the conclusion of the war of 1812 seven other naval stations, to wit: Whitehall, Lake Champlain; Sacketts Harbor, N. Y.; Erie, Pa.; Charleston, S. C.; Baltimore, Md.; Newport, R. I.; New Orleans, La.

In the same way the military operations during the Mexican war brought the navy-yard at Pensacola into active operation, and fully demonstrated the necessity of a naval station on the Gulf frontier; the acquisition of California required a navy-yard in the bay of San Francisco; while, during the late civil war, Port Royal, S. C., Mound City, Ill., and Key West, Fla., became, for the time being, the most important naval bases in the possession of the government.

The operations of the war of 1812 forced on the attention of the government the exposed position of some of the navy-yards on the Atlantic board. Under date of February 22, 1814, the Secretary of the Navy, in a communication addressed to the Senate, writes: "No further steps have been taken in relation to the dockyard [at New York] than general inquiry and proper deliberation in order to determine upon the best site in a central situation.

"The result has decided in favor of the right bank of the Hudson above the Highlands. The motives to this decision were from considering the contemplated dockyard as the nucleus around which a great naval establishment may be formed, comprising wet and dry docks, forges, foundries, boring, rolling, saw and block mills, blast and smelting furnaces. . . . Here also will be the main arsenal and depot of timber and materials of all kinds, and principal dockyard for constructing and repairing ships-of-war. Such an establishment in any of our seaports accessible to ships of the line, would form so great a temptation to a powerful enemy as to render destruction certain, unless protected by forts and garrisons of the most formidable and expensive nature."

These views were fully confirmed by the report of the mixed commission of 1820, which indicated Murderer's Creek, near Newbergh, N. Y., on the Hudson as the best site for a naval depot.

In compliance with a resolution of the U. S. Senate of February 13, 1817, and while the memories of the war of 1812 were still fresh, the President appointed a commission of army and navy officers to report on the "defense of the maritime frontier and the establishment of naval depots and dockyards." Commodore Bainbridge, one of the commissioners, in a minority report lays down the conditions necessary for the establishment of a "naval depot, rendezvous and dockyard," and then expresses the opinion that Boston "possesses in an eminent degree all the great advantages necessary for a naval establishment," concluding his report with the remark that "so extensive a coast as that of the United States requires at least three considerable naval arsenals. "Geographical situation appears to me to mark decidedly Boston, New York and Norfolk as the proper sites: Boston for the eastern section of the country, New York for the middle, and Norfolk for the southern."

The instructions to the commissioners, it should be observed, required an examination of the ports and harbors *east of the Delaware* and as far as Portland, Maine.

The majority report, signed by Gen. Swift of the Engineer Corps, U. S. Army, and Captains Evans and Perry of the Navy, states that "the positions presenting the most importance in respect of good harbors, depots and defensible sites, are to be found in the waters of the Chesapeake and Narragansett Bays." They then proceed: "The Commissioners (except one) are of the opinion that Narragansett Bay presents the best site for a naval depot in the Union north of Chesapeake Bay." They give their reasons in full for their preference.

Following this report came one in 1819, one in 1820 and one in 1821, all bearing on the subject of maritime defenses, and all exhibiting careful study of the whole subject from both the military and naval points of view.

The weight of authority unmistakably indicates a position remote from the seaboard as the best site for a great naval depot, as we have seen from the report indicating the upper Hudson in one instance and the recommendation of "Burwell's Bay on the right bank of the James above Day's Point" by the joint commission of February, 1819.

In those days the calculations were based upon attacks made by wooden vessels propelled by the wind, the heaviest guns being 42 pdrs., having an effective range of 1½ miles; whereas to-day we must provide against ironclads carrying long-range guns of high power. What may be called the "working gun" of the leading naval powers is assumed to be the 8-inch rifled gun, throwing a projectile of 250 lbs. about eight (8) miles.

A single gun of the heaviest of the European ironclads will throw a greater weight of iron than the entire broadside of a line-of-battle ship of 1812. A seventy-four-gun ship of that period could throw at a broadside 1612 lbs. of metal; a forty-four of the Constitution class, 680 lbs., whereas a single projectile of the Italian Duilio weighs about 2000 lbs.*

If, then, some of our navy-yards were, in the days of short-range guns, thought to be in dangerous proximity to the sea, what shall we say of them now when powerful ironclads can, from the open coast, hurl huge masses of iron for a distance of five or six miles or more, according to the elevation obtainable? If to this we add the defenseless state of our principal harbors and the water approaches to our navy-yards, as clearly set forth by our military authorities, their exposed positions may be fully understood.

The reason why the New York navy-yard, taking that as an example, was not sent up the Hudson beyond West Point, to ensure its safety, seems very plain.

As early as 1798 the Secretary of the Navy recommended in an earnest and well argued report the building of 12 line-of-battle ships of 74 guns each, and as many frigates, with 20 or 30 vessels of smaller ratings. This was to establish the outer line of coast defense and furnish the desired security. The frames of 11 line-of-battle ships were actually set up, but the majority of them were permitted to rot away on the stocks. Congress would neither grant the money necessary to complete them, nor the complement of seamen necessary to man those that had been launched. But four of them ever got to sea; that is, in the sense of making a cruise.

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* The extreme range of the 100-ton gun is, by calculation, 13½ miles. A range of from 7 to 10 miles may in practice be counted upon.

Successive administrations finding that, despite the lessons of the war of 1812, Congress was not disposed to augment the navy and coast fortifications to the extent requisite for defensive purposes, felt the necessity of providing for the safety of the navy-yards by throwing them back from the coast and beyond the reach of a sudden attack by a hostile force.

But accessibility from the sea to our own ships is one of the most important considerations in determining the relative values of a site for a navy-yard. It was believed, moreover, that in due time the people of the United States would become convinced of the fact, and so express themselves through their representatives in Congress, that the great centres of commerce on our seaboard (and the navy-yards included within their limits), together with our vast coasting trade, demanded the protection which a fleet of line-of-battle ships and forts alone could render. Under the influence of this conviction the navy-yards on the Atlantic coast were allowed to remain where originally located. They must necessarily, it was argued, receive the protection imperatively demanded by the centres of wealth and commerce of which they form part.

The question "How many line-of-battle ships to supplement the maritime defenses should the United States possess, in order to afford this protection?" is only to be determined after careful study of all the conditions, past, present and prospective, of the problem. But if the Secretary of the Navy found good and ample reason in 1798 for recommending 12 line-of-battle ships, a recommendation Congress tacitly adopted, it is not too much to say that in 1898 we should have at least 18 line-of-battle ships; and frigates or cruisers, and other classes of ships, in proportion.

The more precise term *line-of-battle ship* is used here rather than the modern but indefinite term *battle-ship*. Any vessel, armed and equipped for fighting, may be called a battle-ship. The Petrel, carrying four small guns, was designed for battle, but she would hardly be admitted as part of a fleet composed of such ships as the Indiana and Iowa, ships representing the highest military value. The same may be predicated of the monitor Puritan. Though possessed of great power as a fighting machine, she is deficient in the manœuvring qualities requisite to fleet evolutions: her rôle is a restricted one. Hence the naval tactician must arbitrarily assume certain classes of vessels that, with the requisite manœuvring qualities, can stand, with reasonable chances of success, the shock of battle between opposing fleets, and assign them to the force that is to constitute the line of battle. During the sail period it was generally understood that the 60-gun ship should be the smallest vessel admitted to the line of battle. The naval tactician of to-day requires that there shall be a certain measure of homogeneity in the ships that are to compose the main body of the fleet with which he may be called upon to guard our coasts and navy-yards. In other words, his line of battle must be composed of line-of-battle ships.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE WAR IN THE EAST.

By Captain Richard Wallach, U. S. Marines.

INTRODUCTION.

By Captain H. C. Taylor, U. S. Navy, President of the
U. S. Naval War College.

The war between China and Japan began at a moment when the War College was engaged upon problems of naval campaigns. Some officers had already taken up, as an example of strategic principles, a situation based upon hostilities between those nations, with Corea as a theater of operations. It was natural therefore that actual war coming at such a time should engross much of the attention of the officers in attendance during the session of 1894. At the close of the war I requested Captain Wallach, of the permanent staff of the College, to embody in a series of lectures the military operations of the Chinese and Japanese forces and his commentaries thereon. These lectures were read during the session of 1895, and his method of treating the subject proved so interesting that the Naval Institute invited him to publish them under its auspices.

The special value of Captain Wallach's work lies in the comparisons which his historical studies enabled him to draw between the Japanese campaigns and those of former wars, by means of which each military operation is classified with those in history among which it properly belongs. In the pursuit of knowledge we find little satisfaction in the contemplation of an isolated fact. It is only after many facts of like qualities are gathered into a homogeneous group that we begin to discover those threads of truth with which alone we may weave the fabric of a sound philosophy. Captain Wallach's study of the war in the East classifies the data at hand, and moves forward another step in the military art by assigning the operations at Ping Yang and elsewhere their due relation to certain campaigns of Frederick and other leaders. His work is therefore something more than a correct narrative of military events, and will claim the attention of officers on account of its interesting analogies, by means of which we discern more clearly the principles of success and failure, however different may be the military situations which they dominate.

H. C. Taylor.

The narrative of events contained in these lectures was prepared from various reports from the seat of war, chiefly those published in the Army and Navy Gazette, London, and the New York Herald.

The following works were also consulted and drawn upon, viz.:

The Comte de Paris' History of the civil war in America, Jomini's Art of war, Mercur's Art of war, Soady's Lessons of war, Hamley's Operations of war, Derrécagaix's Modern war, Hozier's Seven weeks' war, German official account of the Franco-German war 1870-71, Dufour's Strategy and tactics, Brackenbury's Field fortifications, Greene's Russian army and its campaigns in Turkey in 1877-78, Johnston's Narrative, James' Modern strategy, in United Service Magazine, Fix's Manual of strategy, Cust's Annals of the wars of the 18th century, Jomini's Life of Napoleon, Von der Goltz's Nation in arms, D'Armit's Intrenched camps, in Journal Military Service Institution, Dodge's Cæsar, Colomb's Naval warfare, Colomb's Essays on naval defense.

OPERATIONS OF THE FIRST JAPANESE ARMY.

In June, 1894, China landed a force of 2000 men at Asan to quell disorders which had assumed such proportions as to be beyond the control of the Corean government. This force was unable to move for a considerable time through lack of preparation for a campaign.

As soon as the Japanese government learned of this step it promptly despatched a force of from 4000 to 5000 men to Chemulpo under convoy of several warships. These troops occupied Seoul without opposition, and cut off the lesser Chinese force from its own frontier and the possibility of succor from that direction. On the other hand, should China continue to throw troops into Corea by way of Asan, there confronted Japan the danger of having its troops hemmed in between two superior forces, since in an invasion of Corea the great mass of Chinese troops would enter it from the north. This danger, however, was averted by the Japanese continuing to pour in troops by way of Chemulpo until their force was self-sustaining. The Kowshing disaster also rendered it highly improbable that Chinese reinforcements would be sent over sea until the command of that element had been secured. During July 27 and 28 several actions occurred in the vicinity of Asan, where the Chinese were attacked in superior numbers. In one of these actions, during a night attack two Japanese divisions fired into each other, doing much damage. The Chinese admit that of the 1500 men lost by their enemy, by far the greater portion fell from their own fire. While the Chinese camp was cut to pieces, the major portion of the troops succeeded in cutting their way through the attackers' lines, retreating to Yoju and escaping to the northward and eastward of Seoul. Keeping to the mountains they eventually, after 26 days of more or less fighting, joined the main body of Chinese encamped at Ping Yang.

This was unquestionably a clever piece of work, as the only avenue of escape was by passing to the eastward of the Japanese force near Seoul, the moral effect of the sinking of the Kowshing leaving little hope of being reinforced by troops from over the sea. The Japanese being in much greater force, their failure to intercept the Chinese can only be accounted for on the ground that they regarded an attempt to march from Asan to Ping Yang, a distance of 200 miles, through such difficult country, as hopeless. For several weeks subsequent to the actions about Asan, a series of combats and affairs between outposts and advance guards took place, the result of the Japanese advance northward.

In the early part of September the Chinese main force occupied a naturally strong position at Ping Yang on the Tatong River, which they had further strengthened with intrenchments, throwing forward advanced posts in the direction of Seoul.

The Japanese, owing to the criminal inertness* of the enemy's fleet, had been landing troops unmolested under cover of their cruisers at Gensan on the east coast of Corea, at Chemulpo, and at Hwangju, at the mouth of the Tatong River This last force the Chinese General Yeh, the same who escaped from Asan, claimed to have destroyed, but as these troops, reinforced by marines and seamen from the fleet, performed such efficient service at the battle of Ping Yang, his statement was apocryphal.

The Japanese converged upon Ping Yang in three columns: the first from Gensan, the second from Seoul, and the third from Hwangju. The paths over the mountains from Gensan were believed to be impracticable for a force of any considerable size, and no great apprehension was felt in this direction by the Chinese, yet the arrival of these troops upon the field with such admirable punctuality demonstrates the skill with which they surmounted all

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*Later information shows that the non-interference of the Chinese fleet was due to orders from the Tsung Li Yamen restricting its cruising limits, and not to its commander.

difficulties, and reminds us of General Gourko's march over the Balkans in 1877.

By the night of Friday, September 14, the three Japanese columns were in position for a combined attack, and each in touch with the others. The first, or Gensan column, advancing from the northward, lay in rear of the stronghold; the second, or Seoul column, composed of several divisions, threatened it from the eastward; while the third, or Hwangju column, approaching from the westward, lay in front of the works south of the town.

Ping Yang, itself a natural stronghold, had been added to by the construction of a series of earthworks with modern armaments and manned by China's finest troops. In the main fort, or castle, close to the city gates, there were three Krupp field pieces and several Gatling guns, while all the troops carried Spencer or Mauser rifles, and there was no lack of ammunition. There were one or more field pieces and several Gatling guns in each earthwork and masked fort. Altogether the Chinese troops were intrenched at twenty-five different points, and besides the main castle there were five other large and well-armed forts,—two to the south and one to the north of the city and main castle, and two on the banks of the river opposite the city. The masked fort to the northward of the castle is reported to have been the best piece of military engineering ever accomplished by the Chinese. These forts were supplemented by numerous fieldworks. On the banks of the river opposite the city, on a hillside among the pine-trees, were two forts, flanked by two fieldworks, with two more in advance.

It was against these works that the Chinese expected the attack would be made, and had gathered there in greatest force. The Seoul column advancing in this direction had been reinforced by another detachment from the south, and was under the command of Major General Oshima, who began the fight by opening fire with his artillery at daybreak on Saturday, September 15, continuing the bombardment until after noon; the Chinese, whose position in this quarter was recognized as exceptionally strong, replying with a brisk cannonade. At 2 p. m. the Japanese infantry advanced, making a feint attack, and under a combined artillery and rifle fire succeeded in capturing the advanced positions, and discovered that the works in rear had suffered considerably from the bombardment. Desultory firing continued during the night with a view to fixing the attention of the defenders in this direction. This proved so successful that the first and third columns were enabled to close in on the rear and right flank to within 100 yards of the works, the Chinese remaining in ignorance of these movements until the real attack commenced at 3 o'clock on the following morning.

The combined attack of these three forces was executed with perfect precision and regularity. The Seoul column advanced against the hillside forts, but were received with such an effective fire from the Krupp and Gatling guns as to cause the commander of the attacking troops quickly to divide his detachment into two wings. As the Japanese troops neared the works the Chinese fire ceased, but when they reached the walls of the fort the defenders made a desperate charge, and a terrible hand-to-hand conflict ensued, in which the Japanese killed fifty of their adversaries with the bayonet at one spot alone, while the rest of the garrison fled, leaving the Japanese in possession of the works. This occurred at 7 o'clock in the morning. In the meantime a cold drizzling rain set in, increasing to a steady downpour later in the day, adding greatly to the discomfort of the attacking forces. By this time the second wing of the Gensan column had captured a hill commanding the works north of the castle. Placing their fieldpieces upon the crest of this hill, they made the works below untenable, throwing their garrison into a panic and causing them to retreat toward the castle and city in confusion. The western column, in two wings, began the advance against the earthworks and forts to the east at 5 a. m., capturing them by 9 o'clock. The Japanese were thus in possession of all the works outside of Ping Yang with the exception of the castle. Several assaults were made against the gates of the castle, but the resistance at these points was most desperate, and it was after 2 p. m. when the victorious troops, almost worn out from the long-continued fighting and their ammunition well-nigh exhausted, finally occupied the castle and city.

The victory was decisive, the Chinese being dispersed and routed in all directions. The victors claim to have killed 2500 and captured 14,500, among the latter the commander-in-chief and three other generals. They also captured large quantities of equipments, provisions, arms and ammunition, with hundreds of colors. The Japanese reports state that the Chinese defended the position with 20,000 troops, and admit that they outnumbered the Chinese nearly three to one. The Japanese loss was estimated at 30 killed and 270 wounded, including 11 officers.

The concentration and attack on Ping Yang illustrate the successful execution of two of the most difficult and hazardous operations known to military science, requiring ability of the highest order. These are the combined march and the night attack.

Combined marches are generally understood to be those in which two or more armies operating upon separate lines from distant bases, or the corps of a single army marching over separate roads, arrive from two or more directions upon a position occupied by an enemy. There is nothing more influenced by chance than these simultaneous movements; the smallest accident may cause their failure and disarrange the most perfectly laid plans; a body of troops may be led astray by the guide, bad roads may retard the march, streams swollen from a storm may arrest a column, an enterprising enemy may attack one of the detachments, indeed any number of accidents may happen, rendering the operation abortive. The greater the extent of these concentric movements the more they are exposed to chance. There is an inherent element of danger, increasing with the distance separating the forces. Such movements are always attractive from the possibility of enveloping an enemy outweighing the chances of having one of the enveloping detachments beaten before the junction is completed.

This happened four times to the Austrian army between July, 1796, and February, 1797. Four times within this period the Austrians advanced simultaneously into Italy for the relief of Mantua, besieged by Napoleon, who, concentrating his forces in a central position, twice beat in succession the separated corps of Marshal Wurmser, and twice those of Lieutenant General Alvinzi, gaining from the former the victories of Lonato and Castiglione, and from the latter the still more important and celebrated victories of Arcola and Rivoli. The last-mentioned victory resulted in the dispersion of the veteran army of the Empire, the abandonment of further efforts for the relief of Mantua, and the transfer of the young Archduke Charles from the field of his successes in Germany to the theater of operations in northern Italy. Again, when France became the theater of war, Napoleon gave striking evidence of the effectiveness of such strategy. For four months he opposed triple his forces, fighting a battle in one place one day, the next marching 25 or 30 miles to attack another enemy. In February, 1814, Napoleon, after beating in detail, with 25,000 men, the four separate detachments comprising the army of Silesia under Blücher, aggregating 60,000, which extended along the Marne River, threatening Paris from the east, and only about 25 miles from it, drove Blücher back upon Chalons. Leaving Marmont with 10,000 men to guard the approaches to Paris from that direction, he lands like a thunderbolt upon the theater of operations of the Grand Allied Army advancing upon Paris from the south, along the Seine. The Grand Army numbered over 100,000, whilst Napoleon's had increased to 30,000 during his march by picking up detachments *en route*. By surprises and attacks upon detached corps, advance guards, etc., he forces the enemy back, who thus forms a junction with Blücher. Napoleon says: "I expected that the allies would profit by the union of such large forces to offer me a decisive battle . . . but to my great astonishment they did nothing, and continued their retreat." Referring to these operations, he says he was convinced that it was only by extreme activity that he could compensate for his great inferiority of numbers. He also says of this march to the Seine: "The cavalry marched night and day; the infantry travelled *en poste*. In this way we made 36 leagues in 36 hours."

Cæsar, when surrounded in Gaul by nations in insurrection, extricated himself from his critical position by similar movements. He gave the Gauls neither time nor means to unite: he fought them successively and beat them in detail.

Napoleon said: "When the conquest of a country is undertaken by two or three armies, each of which has its separate line of operation until they arrive at a point fixed for their concentration, it should be laid down as a principle that their junction should never take place near the enemy, because the enemy by uniting his forces not only may prevent it, but beat them in detail."

Notwithstanding this maxim, the campaign of Waterloo, 1815, which closed the career of this wonderful soldier, opened with the concentration of the widely separated corps of his army upon the field in the presence of the enemy,—an operation attended with such brilliant success as to call forth the highest praise from Jomini. Of it he says (writing as if in the words of Napoleon):

"The plan and commencement of this campaign form one of the most remarkable operations of my life (Napoleon's). Nine corps of infantry and cavalry cantoned from Lille to Metz, by marches most skillfully concealed, concentrated before Charleroi at the very instant that the guard arrived there from Paris. These movements were combined with so much precision that 120,000 men found themselves assembled, the 14th of July, on the Sambre, as if by enchantment. Wellington, occupied in giving fêtes at Brussels, thought me at Paris at the moment that my columns presented themselves on the morning of the 15th to cross the Sambre. So little idea had my enemies of these movements that their armies were not even assembled."

He says that if the allies' generals allowed themselves to be surprised, it must be admitted that they had made their preparations with skill, and admits that to prevent Napoleon from manœuvring to separate their armies, wise dispositions had been made and all rallying points well indicated. "But," he says, "wise as these dispositions were, the celerity and impetuosity of my movements might defeat them." Of the concentration of Blücher's corps upon these rallying points he says: "These movements were evidently based on information received from deserters." Denying this statement, Lieutenant General Cust, British army, says Wellington had "consequently well studied his adversary's last campaign of 1814, when he so successfully separated the Prussian and Austrian armies, and had carefully considered the means of thwarting that favorite manœuver of the French conqueror." In the execution of that manœuver Napoleon was excelled by Cæsar alone.

Now as the advance of the Japanese columns was over widely separated lines of operation from distant points, and as their junction took place upon the battlefield, in the immediate presence of the enemy, we must regard it as a violation of a principle of strategy as set forth by Napoleon.

In the Austro-Prussian war of 1866 several divisions from widely distant bases advanced simultaneously into Hanover and Hesse Cassel. These combined marches were executed with such consummate skill and punctuality that the Hanoverian army was paralyzed, and large quantities of stores, munitions and guns captured.

The army of the Elbe under General Herwarth was to invade Saxony from the north (Torgau) in conjunction with the advance of the first army under Prince Frederick Charles from the east (Gorlitz). This simultaneous movement was also made with such precision and celerity that the King with his court had barely time to quit Dresden before the combined columns entered the city. Prince Frederick Charles gathered his army together about Gorlitz for the advance into Bohemia simultaneously with that of the army of the Elbe, with which he formed a junction near the Iser River, and the second army under the Crown Prince from Glatz. The concentration of the first and second armies took place upon the field of Königgratz, the army of the Elbe striking the left of the Austrian position, the first army the center, and the second army the right and rear, throwing the Austrians back upon Königgratz in confusion. In the Prussian advance upon Königgratz the first and second armies, advancing over different lines from Gorlitz and Glatz respectively, were separated by an impassable mountain barrier for several days, and on issuing into Bohemia either might have been confronted by a superior army before the concentration of the two armies was effected.

We may set this down as another violation of a principle of Napoleon's strategy. But we may also see in it the birth of Von Moltke's strategy—or rather the principles of strategy as applied by him—brought about by the immense size of modern armies, the facility of communication by means of the railroad, by which alone it is possible to keep these immense armies supplied, and the constant supply of information through the telegraph. Those lightning-like movements of Napoleon's armies from one part of the theater of war to another would have been impossible with the huge masses of to-day. In the days of Napoleon it required a constant interchange of couriers, orderly officers, or aids, between the general headquarters and the several corps, in order that, on the one hand, the chief of staff who prepares the orders of march may be constantly informed how they are carried out, and may communicate to the commanding general the real condition of affairs at any moment; and on the other hand, that the commanders of corps may be kept acquainted with passing events, and instructed as to the necessary modifications of details in carrying out the main plan. All this is now accomplished by means of the telegraph. Forces hundreds of miles apart can now be kept in constant communication with a single directing head, and their movements regulated with the precision and punctuality of the parade ground.

Von Moltke in replying to certain criticism on his strategy in uniting the two Prussian armies on the field of Königgratz said: "Armies are now so large that unless you are willing to reduce war to a mere hammer-and-tongs affair, you must have combinations of this kind; it is not possible to have such striking results unless you do bring about these combinations on the actual battlefield; for, if you bring them to pass before the battle, the enemy is likely to know just as much about it as you do; whereas forces which are moving on exterior lines can now be united by the telegraph, and moved with just as much certainty, so far as direction is concerned, as if they were really under the same commander." In Königgratz and Ping Yang we have striking examples of how great and far-reaching may be the effects of such a combination; and it is claimed that in future it will be one of the resources of the great general to bring about, unknown to his enemy, combination of forces from different points which will unite on the battlefield for a common object.

While the telegraph has greatly facilitated these simultaneous movements, it has increased the possibility of failure through interruption of the lines connecting the several forces with each other and with the central authority. In the combined march upon Königgratz, telegraphic communication between the two armies was not maintained up to their junction; had it been, their joint attack might have been so timed as to obviate the risk of separate defeat which the premature onset of the first army entailed. Had the Austrians developed their whole power against the seventh division under General Fransecki, which was exposed across the Bistritz, separated by a wide interval from the nearest division, the result would have had a marked effect upon the battle. This division, engaged since 8 in the morning against the enemy's constantly increasing masses, about 11 o'clock found itself in presence of 51 battalions and more than 100 guns without being able to count upon outside support. Its center first gave way, and the danger of having its wings separated appeared. In this critical position Fransecki vainly called for support. Recognizing the importance of the point occupied, he inspired his officers and troops to defend the position to the last extremity, and by their stubbornness held out until the welcome cry of "The Crown Prince is coming" rang out through the thinned ranks and reanimated the exhausted defenders. This simultaneous advance, although directed by the greatest strategist of our day, who pronounced such movements necessary under present conditions, would probably have had disastrous results had it been made against a more competent general than Marshal Benedek, and convinces us of the danger inseparable from such operations.

In this connection, however, we must bear in mind that circumstances, which are always different, must decide in each particular case that arises; for what is the right thing in one case may be injudicious in another. The course to be followed is greatly influenced by the character and capacity of the opposing generals, the quality of the troops, their armament, state of discipline, etc. In 1654 Turenne passed before the Spanish lines within range, thereby losing several men, which occasioned remark among the officers of his staff who accompanied him. His answer was: "It is true, this movement would be imprudent if made in the presence of Condé, but I desire to examine this position closely, and I know the customs of the Spanish service are such that before the Archduke is informed of our proceedings, has given notice of them to Prince Condé and received his advice, I shall be back in my camp." To make these delicate distinctions and do the right thing at the right time, in the right place, is a manifestation of a true genius for war.

It is fair to assume that the Japanese commander was fully alive to the risk attendant upon his movements if attempted against an active and enterprising enemy, but in this particular case the risk was minimized by the failure of the Chinese to recognize the necessity of the employment of those covering detachments which provide security for their own force as well as information regarding the enemy. The Japanese columns are said to have been in constant communication with each other through the field telegraph, and the intelligent manner in which they performed their patrol and reconnoitring duties kept them well informed of the strength and dispositions of the enemy.

In the Königgratz campaign we find also a wide difference in the practice of the two armies in providing security and information. The Austrian system was much inferior to the Prussian, said to be due chiefly to the want of military education on the part of the officers to whom patrols were intrusted. The Prussian system never failed, never allowed a surprise, while the Austrians were repeatedly surprised and taken unprepared. A Prussian officer on a scout approached the gates of Königgratz on the evening of the battle without meeting a single Austrian and boldly entered the place, where he was captured. With a ready resource he informed his captors that he had come to demand the surrender of the town, which demand was courteously refused by the Austrian commander, who had him escorted beyond the lines without even asking if he was an accredited representative. At the battle of Königgratz the Prussian Guards entered Chlum, established themselves on the Austrian flank under cover of a mist and caused defeat. As a matter of fact the troops of the Crown Prince did not fall in with a single patrol till they actually came into collision with the Austrian line of battle. This same activity in scouting duties is noticeable on the part of the Germans in the war of 1870: the French were unable to shake off the touch of the ubiquitous Uhlan watching their movements.

The Japanese have proved themselves worthy pupils of their masters in this direction, and their great success at Ping Yang, as well as at other points, was contributed to in no small measure by the efficiency of their intelligence department and patrol system. Their intelligence department was provided with accurate maps of the country, with all the roads excellently described, with the passages of the rivers, and their width and varying depths recorded with such exactitude as to enable them to adjust their pontoon trains to precisely the width of each of the rivers it would be necessary for them to cross.

Napoleon says: "Every general who operates not in a desert but in an inhabited country, and yet obtains no information, does not know his trade. The greatest military talent is useless if one is not perfectly instructed as to all the movements of the enemy. The faculty of organizing a system of intelligence is a remarkable quality, and requires a profound knowledge of human nature."

The Japanese had also a well organized and equipped field telegraph detachment, and history does not afford us a better example of the capabilities of this useful appliance when intelligently employed. Within ten hours of the capture of Ping Yang the line was established some distance to the rear, a message flashed over it to the Emperor informing him of the victory, and a reply received congratulating the army upon its success.

Ping Yang stood an obstacle to the further advance of the Japanese as Plevna did to that of the Russians in 1877, but what a marked difference in the result! The Russians stumbled without warning upon a force four times as strong as their own, in a position like Ping Yang, naturally strong, increased by intrenchments, and received the first check to a series of brilliant victories, the moral effect of which was very great upon both belligerents. This crushing defeat occurred on July 20, and brought the Russian advance to a halt. Although two bloody assaults were subsequently made, it was necessary to resort to siege operations, after having called out over 300,000 more Russian troops and appealed to the Prince of Roumania to place his army of 50,000 men in the field. The entire Russian empire was paralyzed from the date of the first collision till the date of capitulation, December 10. The battles up to that date cost the Russians 40,000 men. One of the great objects of the art of war is to be stronger than your enemy at the right time and at the right place. In this particular Ping Yang was a brilliant success, Plevna a disastrous failure. While the Russians could not have scored such a victory as Ping Yang, had they possessed an intelligence department equal to the Japanese and been as proficient in their patrol and reconnoitring duty, they would at least have been spared a crushing and humiliating defeat.

How different might have been the result of the concentration upon Ping Yang had the Chinese been informed of the strength and movements of the Japanese columns. We have seen that the Chinese had 20,000 men, and that the Japanese admitted they greatly outnumbered their enemy. We have also seen that the second, or Seoul, column was the strongest; the other two columns most probably were each less than 20,000, and as the advance of the Gensan column was through such difficult country, by mere bridle paths over the mountains, it is quite probable it was weaker than the Hwangju column, and therefore much weaker than the Chinese force.* With that intelligence of their enemy which they should have possessed, it was possible for them to have received the Japanese as they debouched from the mountain passes, crushing the head of the column as it appeared. Of course this would have precluded any defense of Ping Yang, for we have seen the sound strategy of the Japanese provided for the arrival of the strongest column first, in front of the position, which would have been found empty; nevertheless this would have been far better than the crushing defeat suffered without injury to the victors. The defeat of one of the Japanese detachments would have been a severe blow to their prestige and a needed addition to their own, which was at a very low ebb.

Long experience has shown that the concentrated action of large masses of troops upon a battlefield is impossible at night, and that attempts to continue a general engagement after dark result in confusion, loss of direction, and general disorganization and demoralization of the different units of an army.† The great range and destructive effect of modern firearms have caused the advance of a hostile line from extreme to moderate ranges to be accompanied by such great losses that attention has been strongly directed to the practicability of advancing lines of battle to within short distances of the defensive position under cover of darkness. After the Russo-Turkish war of 1877, which gave us many examples of night fighting, the Russians applied much thought and study to this subject, and the question was debated generally in European military circles. The events in Corea have revived discussion, which is carried on in tactical manuals, setting forth the pros and cons, and submitting regulations which should govern both the attack and the defense.

One of the most remarkable illustrations of a night attack is that upon the formidable fortress of Kars, armed with 300 guns and defended by 25,000 Turks, which was carried, with incon-

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* A Japanese writer claims that they were a very little stronger than the Chinese at Ping Yang, and that the Gensan column numbered only about 1500 infantry with 2 guns.

† An English officer, as a result of observations during the Franco-German war, said: "The nation that first so trains its army during peace as to move and attack with relative facility by night will gain an advantage, which in future warfare will be decisive."

siderable loss, by a midnight assault. Tel-el-Kebir follows next as an example, in which the necessary conditions, as set forth by modern writers,—highly trained troops, well-understood plan, and a knowledge of the enemy's position—existed; and although the assaulting columns were composed of such splendid troops as the brigade of guards, royal marines, and in fact England's crack regiments, and the advance was made without noise or firing a shot, two columns almost came in collision, though the leading was as good as it could possibly be.

The Japanese commander appreciated the requisites of a successful night assault. He had a sufficient knowledge of the position, had established perfect communication between his columns, his troops were under admirable discipline and ably led, and the real attack was made unexpectedly and decisively,—the result of such an uncommonly favorable combination being a victory more decisive than either of the two just cited. Ping Yang stands out a masterpiece of modern warfare. Indeed, the night operations of the Japanese have caused military experts to assert more boldly that in the next war protection will be sought in darkness to bring troops up closer to fortified positions, and that night operations and night fighting will be resorted to on a much larger scale than ever before; and it is therefore urgently recommended that a complete system of regulations for attack and defense be formulated and practiced assiduously.

During the month following the battle of Ping Yang the Japanese drove the Chinese across the Yalu River, occupying Wiju, where they waited the arrival of their siege guns, while their adversaries worked day and night strengthening their works on the north bank of the Yalu. Detailed information brought in by the Japanese patrols showed that these defenses were not so strong as first reports indicated, and led the commanding general to believe that the main opposition would be encountered at Kiu Lien Cheng, 30 miles west of the Yalu and 120 from Moukden, which prediction proved to be correct.

A detachment of 1600 infantry from the main body crossed the river above the Sukochin ferry north of Wiju, turning the defenses at that point, and attacking them in rear expelled the defenders, who abandoned everything and fled down the river, only firing a few rounds. The detachment occupied the works commanding the ferry, and with the assistance of the light draft vessels of the fleet, which now entered the river, covered the passage of the main body, which was completed and the army in position before Kiu Lien Cheng by early morning of October 26. The tactics so effective at Ping Yang were again resorted to, the advance at daylight being in four columns for a combined attack, but notwithstanding that the city was strongly fortified and garrisoned by 16,000 troops, the Japanese scouts found it empty. 30 guns, a large quantity of ammunition, rice and fodder, and 300 tents thus fell into the hands of the victors.

Detachments made to effect a diversion or a combined march, or for any other motive, are condemned by those writers on the art of war whose rules have been deduced from a study of the campaigns of the great commanders of earlier times. Conclusions are drawn from such experiences as the following:

The Great Frederick in 1759, near Dresden, detached General Fink with 18,000 men to cut the communications of the Austrian army with Bohemia. Fink succeeded in getting in rear of the Austrians, closing the way, but being too weak to hold it, was surrounded and fell into the enemy's hands, although he fought bravely triple his numbers, constantly hoping the army would come to his rescue, but the army was in ignorance of his peril and failed to do so.

Napoleon, upon nearly the same ground in 1813, detached Vandamme's corps after the battle of Dresden for an advance into Bohemia, the main body of the French army being still in the vicinity of Dresden. This detachment experienced at Culm the same fate as that of Fink, except that Vandamme attempted to break through the enemy's line and a part of his corps escaped. This operation cost Napoleon 10,000 or 12,000 excellent troops, and also affected very sensibly the morale of his army through the check it received.

Again, during our war of secession in 1861 General Lyon, confronting a greatly superior enemy, detached Sigel's brigade with two batteries—1420 men, forming a fourth of his command—for an attack upon his adversary's rear, at the battle of Wilson's Creek, in southwestern Missouri. Although Sigel arrived upon the field without mishap and joined in the battle, he was not in communication or within supporting distance of the main force, and his column was completely crushed and dispersed.

According to the maxim of these writers that detachments are dangerous, especially on the eve of battle, which holds good to a certain extent to-day, the Japanese commander was guilty of another violation of the principles of war when he detached 1600 infantry across the river to turn the defenses at the ferry. All the same, the movement breathed the spirit of modern strategy as set forth by the best writers of to-day. Hamley, for instance, in his admirable "Operations of war," says: "In the case of attempting to dislodge an enemy by sending a detachment round his rear, the telegraph will both diminish the risk of the movement and increase the chances of gaining its complete results." It is true the river separated this detachment from its main body, but with the first step in pursuit of it by the Chinese, the Japanese would have thrown their bridges, already adjusted, across the river and fallen upon their rear before they could have struck a blow, for there is no doubt the Japanese detachment was in constant communication with headquarters.

After the capture of Kiu Lien Cheng the Japanese army was divided into two columns. The right marched by Feng Huang Cheng, where it captured 55 guns, 1500 muskets, and large quantities of ammunition and general stores, through the Motien Pass to the vicinity of Liao Yang, driving the Chinese before it in the direction of Moukden. The left column marched upon Siu Yen by way of Taku Shan and drove the Chinese through Haicheng toward Liao Yang. On December 17 these Chinese troops were reported by the outposts of the right column, whose commander decided to intercept them in their march toward Moukden. He overtook them on the morning of the 19th at a small village, when they forced some fierce fighting upon the Japanese, and being some 10,000 strong, the position of the Japanese was becoming desperate when a brigade of the left column came up from Haicheng, securing a victory after five hours of the hottest fighting the first army had yet experienced. After this action Moukden was given up as an objective, and a junction was formed with the second army after it had captured Kaiping, on January 10, 1895. Niuchwang, where was massed a large number of troops, now became the objective of the combined armies.

Operations of the Second Japanese Army.

The second Japanese army, estimated at 30,000 men, including coolies, sailed with sealed orders from Hiroshima under Field Marshal Count Oyama about October 17. This force, in 38 transports provided with 400 small boats and lighters, 100 steam launches and 8 light draft tugs, rendezvoused at the mouth of the Tatong River, which point it reached on October 23, and was there joined by the fleet of 25 warships and 16 torpedo-boats. On the morning of the 24th the fleet sailed, followed by 12 transports, the remainder of the transports following that evening. Upon the arrival of the commander-in-chief on the Chinese coast with the main body the following morning, he found that the commander of the advance guard had already landed a part of his infantry, not a Chinaman being in sight. The point selected as the landing-place was a village on the Chinese coast, just north of the Elliott group of islands and about 85 miles to the northward of Port Arthur, the objective of the army.

With the exception of Talien Bay, close to Port Arthur, there was not a decent landing-place on the coast. It was impossible to land at Talien Bay, the Chinese having fortified the coast and laid down submarine mines. This selection was made not because the place afforded any great facilities for landing, but because the road from Wiju to Port Arthur passed nearer the coast there than elsewhere.

The landing was most difficult, the water being so shallow that the steamers had to anchor 4 or 5 miles from the shore. At low tide it was absolutely impossible to land at all, as the sea uncovered a mile and a half of mud. The difficulty of landing 30,000 men, horses, guns, ammunition, wagons, provisions, tents, ambulances—in short, that vast bulk constituting the equipment of a perfectly appointed expedition—under such conditions, I think all officers can appreciate. Using the tide, however, the landing was accomplished in an expeditious manner without the loss of a man. The only accident attending this operation—recognized as one of the most difficult in war—was the destruction by fire of a transport having on board the ammunition and horses of the siege mortars, just as it was about to unload. The ammunition and horses were all lost. The advance on Port

Arthur was begun at once, the army marching in two columns, the right consisting of the first division, the left of the second division.

On the morning of November 6 the first division attacked Kinchow, which was defended by some 1200 infantry and artillery. The guns were poorly served, their firing being weak and badly directed. The outlying works were quickly cleared and panic seized the troops in the inner forts, who fled in disorder, abandoning their guns, standards, and stores, and throwing away their rifles. The first division then joined the second in investing Talien Wan on the opposite coast. This strong position was defended by six forts mounting 80 guns of various patterns. On the evening of November 6 the bombardment of the Chinese position commenced, and on the 7th the works were carried by assault, the garrison of 3000 offering but a slight resistance, retiring in the direction of Port Arthur after firing a few shots.

The advance was resumed on the 18th. The country is very mountainous and the roads execrable, presenting great difficulties to the artillery and supply columns. Five miles from Kinchow, at the neck of the peninsula, the space between the Yellow Sea and the Gulf of Pechili is not a mile and a half wide, one road only runs across it, and a few resolute men could have turned it into a veritable Pass of Thermopylae. This narrow neck once passed, two roads lead to Port Arthur. One, following the shores of the Yellow Sea, reaches the city on the east; the other, running southward along the Gulf of Pechili, enters the city on the north; the bulk of the army marched over the latter. A mixed detachment of one regiment of infantry, a detachment of cavalry and engineers, etc., took the southern road. During November 19 the Japanese covered 25 miles of this exceedingly difficult country, up and down mountains, with a faith in Marshal Saxe's maxim that "victory resides in the legs of the soldiers," the advance guard arriving within 4 miles of the enemy at 8 p. m.

Port Arthur itself lies around a large inlet. From seaward the port is entered by a narrow channel diminishing to less than 300 yards across within the three-fathom line. This channel runs northward from the open sea for a little less than three-quarters of a mile, for two-thirds of which it is enfiladed by a fort placed on a curving spit on the western shore, known as the Tiger's Tail; while another fort on the opposite bank commands nearly the whole passage. The distance of the first-mentioned fort from the entrance is about 900 yards, the second about 600 yards. The bay outside is also dominated by numerous batteries, which cover a front of nearly 4 miles. These works, twelve in number, were nearly evenly divided between the eastern and western sides of the entrance to the harbor. They were armed with about 50 Krupp guns, varying in calibre from 6 to 9½ inches, together with several rifled mortars and rapid-fire guns. The entrance to the port, which was commanded by a hill on either side, from 400 to 450 feet high, was also provided with an elaborate submarine mine defense, supplemented by booms and a flotilla of torpedo-boats. Once the strait was passed, the basin opened out on the eastern side, while on the west the land-locked bay widened suddenly behind the Tiger's Tail into a broad shallow lake. Nature herself had protected this stronghold from a land attack by surrounding it with a semicircular chain of hills from 300 to 600 feet high, both extremities resting upon the Yellow Sea. These hills were crowned with forts connected by miniature Chinese walls, redoubts, and shelter trenches. Across a valley a mile wide, and facing these hills, was another chain of hills which the Japanese seized, the Chinese having failed to occupy them, and established their advanced posts upon the most commanding of them, whence they obtained a good view of the entire Chinese defenses.

On the morning of November 20, the advance guard being the only Japanese troops in position, and most of the artillery some distance away, the Chinese appeared in a new role and began what the Japanese supposed was a very opportune attack, which, had it been executed with any vigor, would most likely have proved disastrous to the latter. As usual, however, it degenerated into a weak demonstration, demoralizing to the troops making it, and encouraging those against whom it was directed. Several shots were fired from the works opposite the hills occupied by the Japanese advanced posts, the shots being directed at the staff officers engaged in studying the ground, after which a column of about 2500 men was seen emerging from the center of the chain of hills constituting the first line of defense. Suddenly a second column appeared advancing towards the Japanese right, and then a third column upon their left. These two columns were each about 2000 strong, and after occupying some hills within range on the flanks of the Japanese positions, waited for the central column, which advanced in fine order about 2 p. m. Two mountain batteries and some infantry from the Japanese main body were brought up in great haste, the guns being posted in good positions on the hills previously selected by the staff. The infantry were partly massed in rear of the front hills and partly extended as skirmishers in front of the guns and between the hills. When the central column was about 1500 yards distant the right mountain guns opened fire, the shells falling in the midst of the leading troops. The column halted for a moment, but a few more shells bursting in the thick of them caused them to turn tail and make for Port Arthur in the wildest disorder. The fire of the guns still pursued them, dropping shrapnel with unerring aim over their heads, completely demoralizing them. While this was going on the right and left columns were simple spectators, fearing to approach any nearer. As soon as the central column had fled beyond range, the Japanese guns paid their respects to the column on their right with the same result, a few shells bursting in their ranks producing a stampede. The right column looked on for a while, but without waiting to be served, turned about and made for their works. All this while the forts were concentrating their fire upon the two batteries, but without effect, their range being too great. By 5 p. m. the last Chinaman had retired without firing a shot.

The remaining artillery as well as the rear guard having arrived, the siege guns were mounted during the night within a mile of the Chinese works. The infantry began the advance at 2 a. m., and under cover of darkness were disposed for the attack. The artillery was posted in the center of the line, commanding the right, left, and center of the Chinese position. The cavalry covered the right flank to prevent the enemy's escape to the westward. The army was divided into a right and a left wing, composed respectively of the first and second divisions, each division being composed of two brigades, with only one battery posted in rear of the center as a reserve. The right wing was to take the three forts opposite them, after which the second division was to attack the enemy's left and the forts in their front.

About 6 a. m. one of the siege mortars opened the fight, and in an instant all the mortars, field and mountain guns, over 40 in all, were pouring shell into the Chinese forts. The Chinese replied promptly with the 12 heavy guns in the three forts on their left, but their practice was bad. The largest of the Chinese sea forts also turned its guns upon the mortars, but without effect, their elevation being too great. The Japanese siege mortars produced little result, their projectiles nearly all falling short, but the field and mountain batteries were served with deadly effect after they had changed their projectiles from shell to shrapnel, having observed that the former had little or no effect upon the walls of the forts, while the latter burst with the utmost precision behind the parapets, spreading death and destruction within the works. The artillery duel lasted about an hour, toward the end of which the fire from the forts became weak and irregular.

As the Japanese guns ceased their fire, the first brigade on the right of the line was led by its chief against the most westerly (or left) of the three forts. Soon after beginning the advance they encountered 1000 Chinese who had sallied from the forts, but a few volleys soon dispersed them. The fort now brought 4 big guns to bear upon these troops, but they advanced steadily under a hail of shell from these guns, supplemented by the fire of a body of infantry behind the parapet. Reaching the foot of the hill, 400 feet below the fort, the brigade halted for a moment to pull itself together, the broken ground now protecting it from the hostile fire. Only a moment, out it came, steadily it advanced up the mountain over this shot-swept zone, without wavering, as if on parade. By 8 o'clock the leading troops were under the parapet, and with a cheer the assault was made and the defenders turned out. The guns of this fort were at once turned upon the two others, but their garrisons seeing the fate of the first fort abandoned them and ran toward the town.

The Japanese left wing was really little more than a mixed brigade, and while it had for its task the capture of the strongest part of the Chinese defenses, consisting of eight forts, upon hills from 400 to 500 feet high, it was not to attack until the works on the Chinese left had been captured, thus taking into account the depressing effect upon their defenders, whilst increasing the ardor of the attackers and inspiring them to greater efforts. This attack upon the enemy's right was to be supported by the heaviest artillery, including 4 long-range guns of 12 centimeters, and was commanded by one of Japan's most promising generals, Kasegawa. The artillery was to reduce the works, when the infantry would make the assault. The execution of this plan however was not equal to its conception. As we have already seen, the transport carrying the ammunition and horses of the siege mortars was destroyed just as it was about to unload. The mortars had therefore hardly any ammunition, and the troops being somewhat new to them did not serve them with such good effect. During the attack of the first division 3 of the long-range guns arrived, but the difficulty of bringing them up to the elevated position selected for them and mounting them was so great that by the time the first gun was fired the infantry had advanced so far to the front as to mask them, and they were of no further use; the consequence was that this single brigade of infantry was confronted with the task of taking these seemingly impregnable forts. It was a little before 9 o'clock that the infantry, which until then had remained hidden, approached in its advance across the valley separating the two chains of hills. During the advance the field artillery, which had been preparing the attack of the right wing, quickly changed from its first position on the left to about a mile from the first of the line of eight forts, and began shelling it. The fort replied briskly, but in a few moments huge clouds of smoke were seen, followed by a terrific explosion. The magazine had gone up and the fort was on fire. As the small shells the Japanese were using were unlikely to cause a conflagration, it is probable that the explosion was caused by the Chinese. The defenders served their guns well, concentrating the fire from the eight works upon the attackers with good effect. Several shells landed in their ranks, raising clouds of dust, earth and stones, but upon clearing, the steady columns could be seen, well closed, marching bravely forward.

At this time the detachment on the southern road along the Yellow Sea appeared on the left, advancing to the attack over a flat unprotected road under the fire of four of the forts, which was now turned upon them. This fire became hotter as the troops approached nearer; the quick-firing guns, revolving cannon and thousands of small arms joined the big guns in their effort to repel the attack. Had the practice with these weapons been at all skillful the brigade would have been completely wiped out; as it was, their advance was so precise and steady as to call forth exclamations of surprise from the foreign attachés who witnessed it. Reaching the foot of the hills across the valley, the trumpets sounded the charge, and up the hill they swept to the assault; suddenly an enormous cloud of smoke was observed and a great explosion was heard, followed by three others; the Chinese had sprung their mines charged with dynamite which had been laid half-way up the hill. Their excitement and anxiety had caused these deadly auxiliaries to be perfectly ineffective, as they were sprung too soon, and not a man was injured. When the smoke disappeared the attackers were seen under the parapets of three of the forts, not in the least affected by what might have proved demoralizing to the best disciplined troops of any western nation. The infantry entered the works a moment later. The column on the extreme left had also captured the fourth fort, and the advance was promptly resumed against the remaining works, which were quickly abandoned.

It was not quite noon when a great cheer rent the air, announcing the capture of the eleven land forts. The commander-in-chief received the reports of his generals, and at once gave the order for the first division to take the town. The road into the town passed between two hills, the one on the right having a battery of 3 guns on it, served by the best gunners the second army had yet been opposed to. On either side of the road were shelter trenches, the troops being armed with repeating rifles. Although the Japanese made the most intelligent use of the ground it was found impracticable to advance under such a galling fire as they received, and it was not until a small detachment crept around on the flank of the trenches, enfilading them and causing their defenders to retire, that the leading troops crossed the bridge and entered the town, about 2 p. m. Attention was then turned to the only fort not in possession of the Japanese. This was the largest sea fort, which, however, was found deserted, its garrison having escaped. It was just 4 o'clock when the Japanese colors floated over this work, and the chief of staff, saluting the commander-in-chief, modestly said: "Field Marshal, I believe Port Arthur is now in the hands of our soldiers."

Thus fell to the Japanese the finest and most perfectly equipped naval arsenal the Chinese possessed. It contained a dry dock 400 feet long—the only one in China capable of receiving their largest vessels,—its numerous workshops were fitted with the most approved plants for the construction and repairing of vessels, the shops and storehouses being connected with the tidal basin by a railway. There were several fine steam cranes for facilitating loading or unloading war material, for the manufacture of which the foundries and other departments were perfectly equipped, even to the torpedo shops, where these weapons were tested and repaired. In the harbor were two small steamers, a fine sailing ship, an expensive dredger, a partially completed gunboat, several hundred tons of steel rails and 450 fish torpedoes. To these must be added about 100 Krupp guns, thousands of small arms and tons of ammunition, and we have some idea of the value of this victory.

A notable feature of the battle of Port Arthur was the employment for the first time of a new weapon designed for use against fortified positions. After the investment of Paris in 1870-71, Germany and other European nations, as the result of observations upon the extent of injury caused to fortified positions by gunfire, went into the matter of providing batteries of light and short howitzers for moving swiftly upon intrenched positions and works, and crushing them by weight of metal and high angle fire. Krupp of Essen succeeded in producing the piece used by the Japanese, which has already been referred to as a siege mortar. This short howitzer, or mortar, although only of 4¾ inches caliber, throws a shell of 80 pounds. The projectile is said to be so long that it protrudes from the muzzle when the piece is loaded. This piece was employed as a general thing in lieu of the regular siege train by the Japanese. We have seen that the best possible results were not obtained from the weapon, owing to a scarcity of ammunition and its novelty in the hands of the troops, who failed to serve it with the efficiency so characteristic of them. It goes to show, however, that the Japanese were possessed of the latest and most improved implements known to their trade.

Port Arthur shows that the second Japanese army was not inferior to the first in its knowledge of the military art. Witness the promptitude with which the staff recognized the fatal error of the Chinese in violating one of the first principles of field fortification, which is, that no work should be commanded by any ground within the range of any weapon likely to be brought against it. The chain of hills facing those upon which were situated the works constituting the Chinese first or outer line of defense dominated the Chinese position, and it was from the tops of them that the Japanese staff carefully studied the defenses, devoting so much time to this operation, and being so near—the valley separating the two lines of hills being but a mile wide—as to become a target for the guns of several of the forts. The staff were quick to recognize the value of these hills, seizing them at once with their advanced troops, and establishing their batteries by night in such positions as to command the entire line of the defensive works. It may be noticed that their tactics in bringing up their infantry to the positions for attack under cover of darkness proved as successful as in previous actions.

We observe that the left wing of the Japanese army, only a little more than half the strength of the right wing, was detailed for the attack of by far the stronger portion of the defenses in the plan of battle; but we must also note that the attack by this column was not to begin until after the works on the Chinese left had fallen. By this disposition the commander-in-chief developed the maximum power of his army. Confident of the ability of the first division to capture the three forts they were to attack, he no doubt believed in Napoleon's dictum that "in war the moral effect is to the material effect as 3 is to 1," and relied upon the demoralizing effect upon the Chinese of seeing their defenses in the hands of the enemy, as well as the incentive this would prove to more heroic exertion on the part of his own troops. Besides, it is a mistake to attack a fortified position with equal strength at all points.

Here we have again the influence of the telegraph upon strategy. By means of the telegraph the position of the detachment advancing over the southern road, which we have seen arrive upon the field with clock-like punctuality joining in the attack, was known at all times.

Port Arthur proves how fully the Japanese recognize the importance of the terrain in military operations. When they halted at the foot of the hills, covering themselves from fire whilst they reformed for the assault, or when the ground was unfavorable for such tactics, as was the case with the detachment from the second division, their adroitness in passing over the shot-swept zone, the troops of the various units throwing themselves flat upon the ground and covering each other by their fire during the forward rushes, they showed themselves to be adepts in the application of modern tactics.

This brilliant feat of arms had but one defect to mar its perfection,—that was the lack of ammunition for the siege howitzers, which in the plans had been relied upon for breaching purposes. This was caused by the burning of the transport already mentioned, but its effect was largely counteracted by the deadly precision with which the shrapnel from the field and mountain guns burst behind the ramparts, the gunners being quick to notice that it was useless to attempt to breach the walls of the forts with these guns, and promptly changing their projectiles from common shell to shrapnel. We must not forget the clever turning movement of the small column which crept around upon the flank of the shelter trenches and battery commanding the flat road into Port Arthur, enfilading them and causing their defenders to retire, carrying out the German creed: "The front is difficult—let us try the flanks."

The errors of the Chinese are only too apparent. First, the narrow neck near Kinchow should have been fortified and tenaciously held. Indeed the ground for several miles in advance of the neck was most admirably adapted to the defense. Second, the outer line of the land defenses should have been established upon the hills the Japanese occupied, and they should have constituted the principal defense, since they commanded all the ground within cannon range, both in front and rear. This position might have been turned into a sort of Chinese lines of Torres Vedras. Had the Chinese been as well versed in outpost duties as their adversaries, they would have realized that the Japanese advance guard, tired and worn out after its march of 25 miles during the 19th of November, might have fallen a prey to an earnest attack during the night, unsupported as it was; or, if the attack on the Japanese on the 20th had been carried through to an assault, it is possible that it might have succeeded. At least they had troops ample to have attacked successfully, as only a portion of the Japanese main body had arrived and a large part of the artillery was not up, while the rear guard was a long distance off. The land forts on the right of the line could have assisted in repelling the attack of the Japanese right wing, whereas they did not fire a shot until they themselves were attacked. There were six general officers exercising equality of command, with results to be expected. In short, we see here, as elsewhere, ignorance, discord, lack of coöperation, and frequently arrant cowardice. Nothing else could account for the capture of this Gibraltar of the East, with losses which were nothing to what they ought to have been. The forces engaged in this battle were reported as about 20,000 for the Chinese, and from 15,000 to 18,000 for the Japanese.

It is impossible to find a parallel to Port Arthur in the perfection of the combined tactics of the land and sea forces. While the water defenses appear to have been sufficient to deny entrance to the Japanese fleet, the vessels were handled in the most skillful and efficient manner outside of the harbor, drawing the harmless fire of the forts, causing them to expend their ammunition whilst husbanding their own. They nevertheless supported the troops in the most superb manner, coöperating with them in a way probably never seen before. Marshal Oyama, from his headquarters on shore, out of sight of the fleet, kept the vice admiral informed of his progress during the action, directing his movements from time to time as the coöperation of the fleet appeared desirable, indicating the successive targets for the guns of the fleet, into which they dropped their shells in conjunction with the field batteries.* While the whole world wondered at the efficiency and versatility of our navy during the civil war as shown by its coöperation with the land forces in the rivers and upon the coast, from which the most valuable lessons known to naval warfare of this description were drawn, we had nothing quite like this almost automatic precision of Port Arthur. Now how were these great forces of the two elements directed by one controlling mind? By that novel and valuable appliance in war which had contributed so largely to their previous successes—the field telegraph. The line from the marshal's headquarters was connected with a signal station within sight of the vessels of

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* A British officer who witnessed this fight from the deck of the Porpoise says: "On a signal from the general on shore, Admiral Ito's cruisers all steamed past the forts just out of range, without replying, only drawing the fire off the torpedo-boats, which did all the work. The torpedo-boats were dashing about in all directions, but were obeying the signals of the convoying cruisers, which again followed the orders conveyed by Field Marshal Oyama's field telegraph."

the fleet, by which means perfect communication was maintained between the two during the fight. In this respect Port Arthur is without a parallel, and alone should be sufficient to convince us of the intelligence and efficiency of these sturdy little fighters in their first war under modern conditions. In addition to this perfection of mechanical conditions, there existed an accord, a singleness of purpose, between the two commanders which it is impossible to surpass, and which perhaps, as much as any other factor, produced this extraordinary action.

Oyama after providing a garrison for Port Arthur detached a division which advanced up the peninsula, with Niuchwang as its objective. This division drove the Chinese northward towards Niuchwang, capturing Foochow and Kaiping. At the latter place some 4000 Chinese were found strongly intrenched, requiring something of an effort on the part of the invaders to dislodge them. An attack was first made upon the two wings, then upon the center, and finally, by a flank movement enveloping the position, the Chinese were routed.

As we have already seen, a junction was now formed with the first army, which occupied Haicheng and the vicinity.

From January 17 to March 4 the Japanese divisions were intrenched in positions from Kaiping to beyond Haicheng, their forward movements suspended on account of the severity of the weather and the difficulty of operations. During this period the Chinese took the offensive, advancing from the direction of Liao Yang in strong force upon Haicheng in two separate attacks, which really were little more than weak demonstrations, and it was only by a *ruse de guerre* that the Japanese commander-in-chief, who was present, succeeded in bringing his enemy under fire. In the second attack, which was a night affair, and which from information furnished by his covering detachments he expected and was prepared for, his dispositions were made in such a manner as to draw the Chinese within 700 yards of his line, when falling upon both flanks, he threw them into confusion, amounting to panic, during which many prisoners were captured. During the same period four or five similar attacks were directed against the Japanese at Kaiping from the direction of Niuchwang and Yinkow, the port of Niuchwang.

The Japanese now resumed their advance upon Niuchwang.

On February 28 the force at Haicheng routed 15,000 Chinese encamped between the roads to Liao Yang and Niuchwang, thus clearing their flank and rear of the enemy; and four days later two actions came off. The force from Kaiping captured all the defenses of Yinkow, on the south and west, on the left bank of the river; and two divisions from Haicheng attacked Niuchwang itself, where the Chinese did some excellent street fighting, only yielding street by street, keeping up the contest from 10 a. m. till 11 p. m., and leaving 1880 of their own and 200 of their enemy's killed and wounded as evidence of the stubbornness of their defense. The advance was continued, after this victory, against a large body of Chinese strongly posted at Yenchaitai on the west bank of the Liao Ho—which was still frozen over—15 miles west of Niuchwang.

On March 6 the dispositions were made for a combined attack in three columns, from the east, northeast and northwest. At 7 a. m. the bombardment commenced, and was continued until 10.30 o'clock, at which time, under cover of the artillery, three columns stormed the position. The defenders at first fought stubbornly, but being outnumbered eventually broke and fled with a loss of 2000 men. The town was set on fire by the Japanese shells, and by night was burned to the ground. With this action the operations in Manchuria were brought to a close, the armistice preceding the declaration of peace following closely upon it.

In reviewing the actions of the first and second armies, which bore the brunt of the fighting during this war, one is struck with the consistency with which the Japanese applied one of the most important elements of modern tactics, that is, a proper preparation by artillery fire of the point of attack before the assault is made. We find no disregard of this necessary precaution such as we remark in the Franco-German war of 1870, as evidenced by the admonitory order of the King of Prussia upon that subject, nor such as was so frequently exhibited by the Russians in 1871, particularly in the earlier battles of Plevna, which their unnecessarily great losses attested. On the contrary, we note the most intelligent coöperation of the two arms, each in its proper sphere.

Of the stuff of which the Japanese infantry and gunners were made we may form some opinion from the foregoing narrative.

As to the cavalry it is hardly necessary to say that the theaters of operations were not adapted to the employment of that arm to any great extent. They were most efficient and valuable however in outpost and patrol duty, acquiring a reputation in this direction hardly second to that of the sister arms. That there was no Japanese Bredow was solely from lack of opportunity. One incident which occurred on the march down the peninsula to Port Arthur may help to convince us of this. On November 18 a body of Japanese cavalry of inconsiderable size, forming the leading detachment of an advance guard, came in contact with a mixed detachment of Chinese infantry and cavalry 3000 strong. The Japanese charged, became surrounded, were rescued by a company of infantry from the advance guard, who in turn were hemmed in. The cavalry charged repeatedly and furiously through the Chinese cavalry, releasing the infantry and covering their retreat,—not quite up to Bredow's work at Mars-la-Tour, but very good for the hardy little ponies many of us are familiar with. As may be imagined, this cavalry was lightly mounted, but equipped in the most approved style, even to French jackboots, their arms being the saber and short carbine.

OPERATIONS OF THE THIRD JAPANESE ARMY.

The third Japanese army, having for its objective Weihaiwei, the second Chinese arsenal, at the entrance to the Gulf of Pechili, was composed of the Sendai division, which sailed from Hiroshima early in January for Talien Bay, the point of rendezvous, and the Kumomoto division, which formed part of the second army at the capture of Port Arthur. This force of about 25,000, with 12 field guns, 36 light mountain guns and 12 mortars, sailed from Talien Wan in two detachments, the first on January 19, reaching Yung Ching at daybreak the following day. Immediately upon arrival, a force of marines in boats from the fleet landed in the face of a feeble fire from an earthen battery of 4 guns, whose defenders were dispersed by the fire from the guns in the boats, and the marines advancing in a deep and heavy snow completed the rout. The beach having been cleared, the landing of the troops began, and by night the advance guard had captured the works at Yung Ching by assault and the main body was on the march thither. On the following morning the second detachment arrived and completed its landing during the day. About this time a small force was landed from the vessels of the fleet under cover of their guns at Teng Chow, west of Weihaiwei, as a diversion, but this force was withdrawn a little later.

From Yung Ching the country breaks from a gently rising plain into a succession of hills and valleys, the declivities unusually sharp and steep. Deep snow covers the ground from December to the end of February. Five ranges of rocky hills running from 1000 to 2000 feet high intersected the line of march. The difficulty of transporting an army over 30 miles of such country, carrying every pound of fire-wood and food, besides ammunition and stores, will be readily recognized. The two divisions advanced over two separate roads, the Sendai division by the inner road, and having with it all the field guns, it being impossible to transport any vehicles whatever by the track nearer the coast, over which the Kumomoto division advanced. When we remember that the thermometer during this march stood at 12 degrees Fahrenheit, we may compare it with operations in the Crimea, not forgetting that here a high, seemingly impracticable mountain is thrown in every now and then, that no railroads exist, that mere footpaths are substitutes for roads, and that food is terribly scarce at all times.

Weihaiwei is by nature perfectly fitted to protect a fleet. It is landlocked on three sides, and three large islands heavily fortified guard its mouth. The hills on the three landward sides range from 1200 to 2000 feet in height, and the eastern arm was protected by five first-class forts constructed by German experts at great cost and armed with Krupp guns. In the harbor at the time of the attack were 6 ironclads, 8 gunboats and 12 torpedo-boats. Mine fields were laid between the island of Liu Kung and the eastern and western arms of the mainland. A line of booms was also placed just inside the mine fields. The town lying on the west side of the harbor, enclosed by hills on three sides, was surrounded by a wall 25 feet high and 40 feet thick at the base. This wall was rectangular in shape and pierced by four gates at the four chief points of the compass. The naval workshops were situated on Liu Kung Tao, upon the summit of which was a signal station 510 feet above the sea, commanding an extensive view of the land and sea approaches. Across a valley on the highroad to Chefoo a line of intrenchments had been thrown up. On the top of the hill to the right, a difficult height to climb, 3 field guns had been mounted. The strength of the garrison of the eastern forts was 3000 men, while the same number defended the western and northwestern forts, and 1500 men were in the forts on the islands. The whole of these defenses were under the command of Admiral Ting.

As already stated, the Japanese army advanced in two columns, the Sendai or second division taking the inner route, of a somewhat circuitous nature, in order to attack the western forts, and the Kumomoto or sixth division following a path near the coast against the eastern forts. The sixth division arrived in front of the eastern forts on January 30, and by night had occupied all of them, the Chinese making no defense worthy the name. Fifty gunners were landed from the fleet and the guns turned upon the Chinese fleet.

The task of the second division was a little more difficult. Owing to its longer and more difficult march it did not arrive before the western forts until three days after the eastern ones had fallen and their garrisons had fled to the western,—at least those who did not continue on to Chefoo. The division was divided into two wings, the right advancing from the southwest, the left more to the northward advancing over the Chefoo road. The right wing encountered little opposition and found the southern forts of the western series deserted. The left wing, on the contrary, encountered 2500 Chinese with 4 guns well posted in the mountains about 12 miles west of the town, and an action came off lasting from 11 a. m. till 2 p. m. in the midst of a blinding snow storm, accompanied by a fierce wind blowing the frozen particles in the face, rendering it almost impossible to see any distance. After an effective use of shrapnel the charge was ordered, resulting as usual in the retreat of the Chinese, part by a path towards Chefoo, the remainder scattering in the mountains. The road to Chefoo was now clear of Chinese and the telegraph between that place and Weihaiwei cut. All the forts to the north and west were now occupied without further resistance, as their garrisons abandoned them at the first approach of the Japanese, and Admiral Ting had sent men from his fleet to demolish the works and disable the guns. The Japanese, however, established their field guns and mortars in these works, or rather above them, and plied the decks of the

Chinese vessels in the harbor so effectively as to keep the men under cover continually. Fighting between the mainland forts and the Japanese fleet on one side, and the remaining Chinese vessels and forts on the islands on the other, continued until the morning of February 12, when terms of capitulation were arranged; and on the 17th the Japanese entered the harbor, taking possession of the forts on the islands, the torpedo stations, workshops, and 2 ironclads, 1 cruiser, and 6 gunboats, with an aggregate tonnage of 12,660. Thus disappeared the last vestige of Chinese power upon the sea.

Here, for the first time, we observe a want of that perfect punctuality which existed in all other concentrations upon the field of battle, and a consequent want of the usual simultaneity in their combined attack. We may account for this in two ways: first, communication between the two columns and headquarters was probably not maintained, through the impossibility of using the field telegraph on account of the difficult country through which the advance was made; second, being stronger in numbers, immeasurably so in *morale*, his troops fresh from the field of a great victory, eager to meet an enemy fighting almost in his last ditch, the Japanese commander did not feel it necessary to hold his right column until his left came up; and we cannot, therefore, accuse him of assuming any undue risk.

While the fleet coöperated in the heartiest way here as at Port Arthur, performing its part in the most skillful and efficient manner, its task was of a secondary nature—mainly to draw the fire while out of range and to watch the entrance to the port. Both Port Arthur and Weihaiwei were essentially land victories, and this fact alone shows the victors to have been cognizant of the modern conviction, arrived at after a study of the operations before Charleston, Vicksburg, Fort Fisher, and Alexandria—that the fire of a ship is altogether unable to breach or seriously damage a properly constructed parapet—while such unarmored vessels as composed for the most part their fleet would have been riddled, if not destroyed, in such an unequal contest. We see them wisely, therefore, refraining from futile attacks from the sea, except in support of the principal attack on land, which would result in a useless expenditure of energy and ammunition.

In the defenses from seaward in both of these Chinese maritime fortresses we find the moral effect of submarine mines confirming the lessons of the Franco-Prussian war, where these most effective auxiliaries paralyzed the offensive power of the French navy, its greatest effort proving abortive through dread of them. Submarine mines supplemented by booms in rear of the mine fields proved wholly sufficient to keep the Japanese vessels out of the harbor.

Port Arthur and Weihaiwei have frequently been referred to as commanding the entrance to the Gulf of Pechili, and their tactical value greatly overrated. Such a strong analogy exists between the importance and functions of a strongly fortified naval base and a land fortress or intrenched camp, that an exposition of the place of the latter in military warfare may enable us to place a proper value upon the former.

Napoleon says of fortresses: "It is true they will not in themselves arrest an army, but they are an excellent means of retarding, embarrassing and annoying a victorious enemy." According to Prussian theories, fortified places should fulfill certain strategic conditions. They should protect important cities, supply-depots, or depots for troops; should defend communicating roads or important passes; should serve as points of support or pivots for either defensive or offensive operations, and as a refuge from pursuit. Fortresses near the flanks of lines of operations have frequently been found, if not of the first importance, yet of such value as to prevent their being ignored by a commander who sought for success in his operations, for from them expeditions may be made upon the lines of communications of an army, and its flanks may be so constantly menaced as to endanger its advance. It has been a common mistake, however, to treat such works with more respect than they deserve, and to besiege, invest and blockade them. Jomini says: "Formerly the operations of war were directed against towns, camps and positions; recently they have been directed only against organized armies, leaving out of consideration all natural or artificial obstacles"; also: "An invading army may pass by fortified places without attacking them, but it must leave a force to invest them or at least to watch them." Thus Wellington and Blücher in their advance on Paris after Waterloo detached small bodies to mask the frontier forts, while the allies of 1793 delayed their advance across the frontier until they had captured the fortresses upon it, the delay enabling the republican armies to rally and reorganize for the defense and eventually to assume the offensive and to commence that career of victory which continued with few intermissions for eighteen years. Jomini says: "Some have attempted to draw a parallel between the efforts of 1793 and 1815. . . . But the allies of 1815 acted very differently from those of the first invasion; they did not, like Mack and Coburg, pass three months before Valenciennes; the times had in all respects changed."

"An excessive tendency to the employment of fortifications has its origin in a feeling of moral weakness. Fortresses are of service only in a war against a superior enemy. But the weaker may be morally strong, and in this case only will it make a judicious use of fortifications. They are, on the contrary, dangerous for the side which is morally weak. For such a nation they have an irresistible attraction. Persuade a people that the center of gravity of the country's defense is to be found behind the ramparts of its fortresses, and long before the necessity arises you will see the army recruited from this people fleeing to these defenses, and if there is not found behind these walls the anticipated security, the fate of that country will soon be decided" (Blume's Strategy). A French writer as early as 1628 says of them: "The strongest of them do not hold out six weeks; the best cannot take care of themselves without an army close at hand"; and Napoleon says: "It is upon the open field of battle that the fate of fortresses and empires is decided."

According to recent French writers, it may be admitted to-day that a fortress ought never to be considered as a base of operations for an army; that is to say, it is insufficient to furnish the army definitively with a refuge in case of defeat or a pivot for its offensive operations. That it should temporarily serve the army for shelter, that it should be a *point d'appui* in strategic manœuvers, that it should cover concentration or a movement by controlling the means of communication of which an enemy must make use to harass these different movements,—all this is indisputable. But in no case ought an army to shut itself up in a place, or even to take refuge there sufficiently long for an enemy to be able to complete the investment thereof.

What other deductions is it possible to draw from modern history with such examples as Metz, Vicksburg, and Plevna? In the first place, the security which Bazaine supposed would be his salvation proved his ruin. Instead of fighting his way through to Chalons, where McMahon was covering Paris, as he had reported he would do, he allowed himself, at the head of about 125,000 men and 390 guns, to be driven off the Verdun road and sealed up in Metz by 72,000 men with 246 guns. It would seem from the German official report of this war that they expected exactly what happened, and in discussing the possibility of breaking the lines of investment, would say: "But Marshal Bazaine might hope in all cases to find his line of march open, to sever temporarily the but weakly guarded communications of the Germans, and although not without considerable difficulties as to supply, to escape with a large part of his army to the southward." When he did make his sortie he had given the Germans time to strengthen their lines sufficiently to repulse his attack, although conducted with skill and vigor by General Le Boeuf with his own corps.

Great armies which are shut up in a fortress after lost battles are, as the history of investments from Alesia down to Metz proves, always lost. Among all relations between fortress and field army, the latter must make it a supreme rule never to allow itself to be thrown into a fortress. It is always better to use it as a support, which enables the field army to keep its full freedom of action. An army can easily be got behind fortifications, but only with difficulty back again into the open field, except it be that strong help from without lends it a hand. Fortresses protect the troops they contain, but at the same time anchor them to the spot.

Vicksburg was very similar to Metz. In reply to an order from General Johnston to move out and attack the enemy near Clinton, General Pemberton, then behind the Big Black, near Vicksburg, overrating the value of that place, which had been passed by Porter's squadron, said: "My own views were expressed as unfavorable to any movement which would remove me from my base, which was, and is, Vicksburg." Upon receipt of this, Johnston's instructions to Pemberton state: "If you are invested in Vicksburg you must ultimately surrender. Under such circumstances, instead of losing both troops and place, we must, if possible, save the troops. If it is not too late, evacuate Vicksburg and its dependencies and march to the northeast." This order was not obeyed. According to General Grant's report, the investment of Vicksburg was completed May 19, and by July 4 it had surrendered.

Plevna, the last of these three famous intrenched camps, will ever stand as one of the most brilliant military operations of history, completely arresting the Russian advance and paralyzing the whole empire for five months, straining the resources of a mighty nation, yielding only to a siege and costing the besiegers 40,000 men. Yet its commander failed to comprehend its limitations, and by overstraining broke them, and thereby lost his whole army of 40,000 men. Like the commander at Metz, Osman Pasha made a brilliant effort to break through the lines of investment, but like the former commander, postponed it until it was too late to be effective. Indeed, General Todleben, the great Russian engineer, chief of staff of the besieging army, asked the Turkish chief why he did not retreat in October before the Russian reinforcements were all in position and the investment complete. His answer was that up to the day of his sortie he felt sure the Russians would continue their attacks, and he felt equally sure that he would be able to defeat them with great loss. He gave it as his opinion that the system of intrenched camps with modern breechloaders is admirable so long as the enemy has not troops enough to surround them. But it is their fate to be invested, and then they are doomed. Up to the time referred to, Plevna had brought the Russian operations to a standstill for three months, and had done all that could be expected from it. His failure to relinquish the security within its walls and save his army was the great defect of one of the most brilliant campaigns on record, which had placed the Turkish commander in the front rank of modern generals and gained for him the title of Conquering Osman.

All three of the commanders referred to failed of a just appreciation of the value of a fortified position in connection with an active army. General Brialmont, the great military engineer, says: " To know how to utilize the passive force of these positions for the profit of the active work of armies will always be the characteristic of great generals." It is quite clear then that fortified positions should be regarded solely as auxiliaries of the active force; that more than one good commander has been lured to destruction through the fatuous belief that in their protection lay his salvation. " Fortifications are good servants, bad masters."

After a few words upon Port Arthur and Weihaiwei from a purely military point of view, I shall endeavor to show how applicable what has been said of fortified positions in connection with land operations is to maritime fortresses or strongly fortified naval bases in war upon the sea.

Port Arthur, as we have seen, lay on the flank of the communications of the Japanese army operating in Manchuria, and an active army basing itself upon that stronghold might have harassed the invading army—if it did not cause it to make a great detour to drive the defenders within their walls. An English writer says: "There is no doubt that this operation, taking up a flanking position, will be much oftener used in the war to come, on account of the sensitiveness of the modern army to its communications, and the fact that if you are invading my country . . . you dare not leave me with a field army on the flank of your communications without turning aside and thoroughly beating and dispersing me first." Substituting sealing up in the Liao Tung peninsula, by fortifying and holding with a small force the neck of land at Talien Wan, for beating and dispersing, we fulfill these requisites with regard to Port Arthur. As has been pointed out, the neck at the head of the Liao Tung peninsula, between Talien Wan and Kinchow, is the key of the position; and that this was recognized by the Japanese is shown by the tenacity with which they clung to it in connection with Port Arthur during the negotiations which followed the close of the war. Consenting to relinquish the conquered territory in Manchuria, they at first decided to fight before abandoning the peninsula from Talien Wan, realizing that by turning it into a vast intrenched camp capable of harboring an army of any dimensions, which upon short notice could be concentrated there, they commanded the situation in the East upon the land.

Command of the sea would have been necessary on the part of the Chinese for the employment of Port Arthur as a base of operations against the Japanese communications, as the Japanese army in Manchuria could have cut off all supplies from landward; and it would be equally indispensable to the Japanese in keeping their intrenched camp referred to above supplied.

After the invaders had advanced well into Manchuria, assuming their objective to be Peking by way of Moukden or Niuchwang, Weihaiwei might have harbored an army which would have proved a constant menace to the base of an army operating against Peking from the southern shores of the Gulf of Pechili, in conjunction with a force in Manchuria.

It was not on account of their offensive qualities that the Japanese deemed the reduction of these fortresses necessary. Admiral Colomb says in his "Naval warfare": "In all attacks made over sea against territory, we shall note one almost universal rule—no attacks of magnitude are ever known direct from a distant base." It is clear that with Peking as the objective, a base upon the Gulf of Pechili would sooner or later become necessary. While we have seen an army operating northward after the capture of Port Arthur, we notice its base was Talien Wan, at which point the third army was also concentrated, and from which it embarked. The natural base of operations against Peking is on the shores of the Gulf of Pechili, at the mouth of the Peiho, or at Shanhaikwan, whence there is a railroad to Tientsin. The possession of Port Arthur and Weihaiwei by the Japanese meant the command of the sea, with the ability to select this base. Supposing the strategy of Japan to have contemplated a simultaneous movement upon Peking by three armies advancing from Wiju, Port Arthur, and Weihaiwei as primary bases, around the Gulf of Liao Tung and Liao Chow Bay,—and their movements up to the moment of the cessation of hostilities make this appear quite possible,—successive bases would have been taken up along the shores of those waters as the troops advanced, in order to shorten their lines of communication.

While the fortresses lay on the flanks of the communications with the home bases, they were of themselves tactically a negligible quantity; their guns were harmless. Their great value was as adjuncts of an active fleet. As harbors of refuge for the Chinese fleet operating against the lines of communication of the enemy, they were of inestimable value. Here was a field pregnant with possibilities. To swoop down upon some belated cruiser or luckless transport with a superior force, to send out among the islands numbers of torpedo-boats to operate in the channels under cover of darkness, harassing and retarding the operations of the enemy,—herein lay the value of the strongholds. It would have been foolhardy for the Japanese to have attempted operations along the shores of the Gulf of Pechili with these fortresses upon their flanks and rear harboring a fleet. Admiral Colomb is authority for the statement that "no fleet can be secure against interruption in any operation, such as the transport or landing of troops, or a territorial attack, so long as possibly interfering naval forces of the enemy are unmasked or free to act against it."* But the fortresses were merely auxiliaries of the fleet, to be relinquished upon the first appearance of the danger of being masked or sealed up. The Chinese commander, however, like those of the armies of Vicksburg, Metz, and Plevna, courted destruction by clinging to his base until it was too late to escape. The instant the blockade from seaward was completed the fate of the fleet was sealed. Suppose it did require the entire Japanese fleet to mask it, the sea was left open to the undisturbed movements of their transports, and their supplies assured. While I do not intend to discuss the naval operations of this war, I cannot refrain from calling attention to the possible result of the abandonment of its base by the Chinese fleet, forming a junction with the southern squadron, and becoming that "possibly interfering naval force" referred to by Admiral Colomb.

To the Japanese fleet, Port Arthur was a pearl without price, with its perfect facilities for docking, repairing and refitting, saving a journey of 1400 miles to the home dockyards, with the attendant danger of destruction or capture to the detached vessel. The importance of its possession, or of its counterpart across the water, needs no argument—a glance at the map is sufficient. Indeed it is difficult to find a war in which the command of the sea was fraught with graver consequences. Japan's insular position, her great distance from the theater of operations, with the

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* In this connection Captain Mahan is quoted as saying, referring to the Chinese convoying fleet and the action at the mouth of the Yalu: "The prominent lesson of the engagement was that it is necessary that the fleet convoying transports should be decidedly superior to the enemy. . . . The whole affair illustrates the extreme difficulty of the attacking movement across the water, unless the attacking force had the control of the water absolutely, . . . The question was in this case whether it was worth while to take such risk for the sake of landing troops." Referring to the Chinese attempt to carry a force across the water, Captain Mahan pointed out that the incident showed that the mere existence of a hostile fleet did not constitute a deterrent force upon the movements of a resolute man. The fleet "in being" was doubtless a most important factor to be considered in making such an attempt, but it was plain that that fleet would not deter a man who saw that the object of his attempt was sufficiently important to justify the risk taken. What remains to be seen is whether the object accomplished was such as to justify the risk.—(Remarks of Captain Mahan published in the Army and Navy Gazette, London, after the battle of the Yalu.)

resulting long lines of communication, all made it peculiarly desirable to her. Without it, the phenomenal campaigns, which astonished the thinking men of the military world not less than those of 1866 and 1870, would not have been possible. That this was recognized is shown by the promptitude with which she gathered herself for a superb effort for its attainment, the result of which is attested by the disappearance of her enemy from the water, so far as active operations went, after the fleet action at the mouth of the Yalu. From that date the invasion was a triumphant march, made possible by the decisive victory upon the sea.

If we bring ourselves to a realizing sense of the brilliancy of the Japanese operations which I have attempted to outline, we are at once struck with a desire to know what were the causes which produced such results. We cannot attribute them entirely to the feeble resistance they encountered, which in no way detracts from the soundness of their strategy and tactics. Indeed, some less skillful commanders might have committed the not uncommon fault of underrating the enemy, which would almost have been pardonable. On the contrary, they observed the greatest precaution whether on the march or in bivouac. Like the Germans in their last wars, their patrol system never failed, and as I have said, contributed in no small degree to their success. It is to be regretted that more minute details of the tactics and formations used in attack and defense have not been received, but from the general knowledge we possess of their operations we have every reason to believe them to have been the highest type of modern ideas in that direction.

It is claimed that superior strategic ability, superior organization, and greater activity contributed more to the successful concentration of the Prussian armies and the victory at Königgratz than superior armament. It is also claimed that the victorious campaigns of the Germans in 1870-71 were the result of organization; that they were due to the organization created by Von Moltke, rather than Von Moltke himself,—to the system, not the man. So also were the admirable operations of the Japanese the result of organization—organization and preparation.

The strategic function of an army may be divided into two periods: first, a period of preparation for war, incident to times of peace, embracing a study of the theater of operations and of the resources of the enemy, and the preparation of the plans of campaigns; then a period of execution, which follows the declaration of war and during which operations are effected according to the plan established, or at least in conformity with a general idea, serving as a basis for the plans of the commander-in-chief, which the more or less unforeseen events of war often modify. The plan formulated by Von Moltke in 1868 unfolded itself in 1870 with almost mathematical regularity and in conformity with settled anticipations.

General Trochu says: "Of all things which contribute most directly and effectually to the success of a military undertaking, *preparation* holds the first place. Without doubt, the genius of the man who conducts the war may sometimes rule its events, but this only in a certain measure and for a limited time. And history tells us that the greatest military geniuses of the world, Caesar and the Emperor Napoleon, to wit, who had so many grounds for trusting alike in their inspirations and their fortunes, did not disdain preparation, on the contrary, that they applied themselves entirely to it and made a thorough study of it as a science from which they hoped great things." In a recent speech, Prince Bismarck, in referring to the wars which led to the unification of Germany, said: "After Sadowa (Königgratz), the principal point with me was that war with the French was not to come too soon, and that we should not be forced to begin it without proper preparation."

Preparation includes, first, a study of the theater of operations and of the resources of the enemy, then the drawing up of a plan of operations and a system of transportation. The strategic importance of a theater of operations often depends upon its topographical characteristics. We have, therefore, two points of view from which it should be examined: first, topographic, having for its aim the study of the features of the ground; second, the strategic, designed to determine their military importance. The task of making a reconnaissance of the theater of operations from this double point of view is one of the most important duties of staff officers.

How thorough had been the work of the Japanese staff is best shown by the remarks of a prominent cabinet minister. When speaking of this war he said: "It has been inevitable for ten years. Steady preparation has been made for it. Every road in Corea and eastern China was surveyed by our War Department years ago. We had timbers measured and cut for bridges over their streams. Every fort and its armament was familiar to our officers. Our sheet-iron stoves for the soldiers in the winter campaign were made before war was declared. Our transport service was as well organized as our navy, and there were no cartridges made of sand, you will observe, in the belts of our troops."

Under the heading of plans of campaign, Lieutenant-Colonel Fix, in his "Manual of strategy," quotes Colonel Vial, a French writer, as follows: "The study of the part which the ground plays is indispensable before entering upon the campaign. In 1805, when the Emperor foresees the war with Austria, he sends his generals, Murat, Savary, and Bertrand, through Germany under assumed names, charged with studying the ground and reconnoitring the roads, positions, water-courses, mountain chains, bridges, defiles, and means of subsistence. In 1866 the Prussian government, foreseeing the war with Austria, sends a large number of officers to execute similar reconnaissances in Bohemia. Finally, in 1870, everybody remarked the perfect knowledge of our country possessed by the Germans; in many respects they knew our ways of communications, the accidents of the surface and our resources better than we did. All of which shows how advantageous it is to study in advance and with care the ground upon which we are to operate."

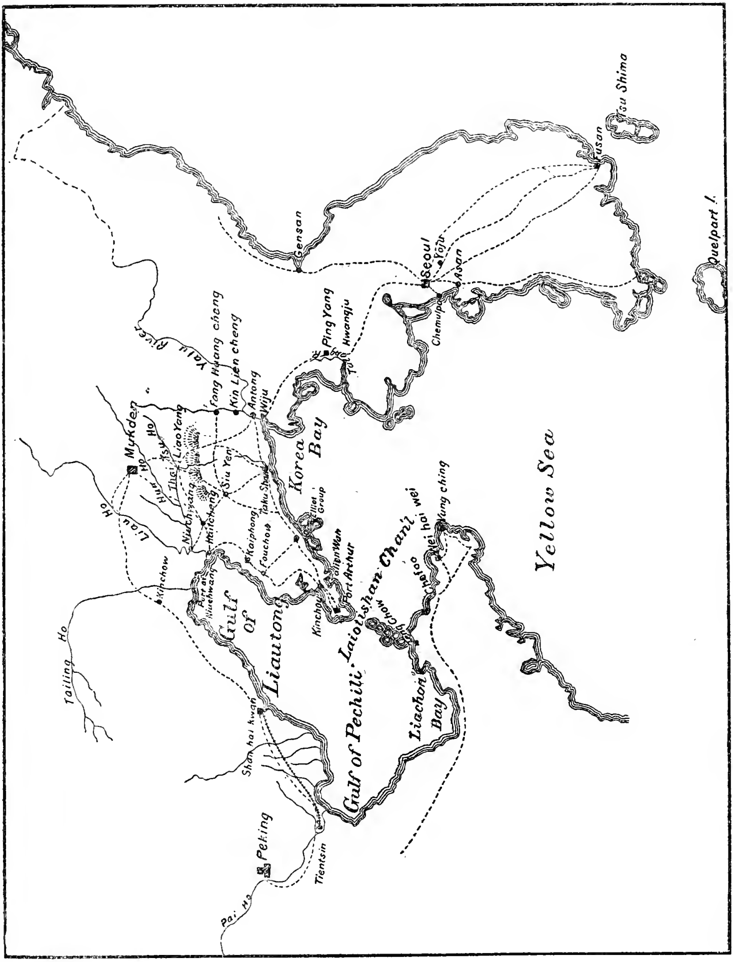
A British officer who witnessed the mobilization of the first Japanese army and its transfer to Corea, when comparing it with the Crimea and Wolseley's expedition to Egypt, asserted that such a transport and commissary service had never been seen in the world. The truth is, the Japanese have proved themselves to be masters of the science of logistics.

Even to the minutest detail of the personal comfort of the soldier was their preparation absolutely perfect. In addition to the stoves referred to, their winter uniform was designed to afford the greatest protection against the rigors of a Chinese climate. Every soldier, besides his uniform of heavy dark blue waterproof cloth, was provided with a blanket overcoat, nearly a quarter of an inch thick and approaching felt in density, yet permitting perfect freedom of action. A heavy blanket and several pairs of thickly plaited straw sandals were also provided every man by the clothing department. These sandals, worn outside the ordinary Japanese foot-gear, in this case made of heavy cloth and padded with cotton, proved more effective against the snows and ice than fur socks and riding boots. The military glove, especially designed for this campaign, was the most unique portion of the altogether admirable equipment. This gauntlet was made of flexible felt, yet thick enough to keep out the severest cold of the almost Siberian climate. In form it was an improvement on the old mitten, having a thumb and a place for the index finger, which, midway down it, had a slit with a flap to allow the bare finger to be used to pull the trigger of the rifle. The men were also provided with heavy cloth gaiters. Where do we find a more thorough preparation? It was not surpassed by Prussia in either of her late wars. What a contrast it was to the Crimea with its indescribable sufferings!

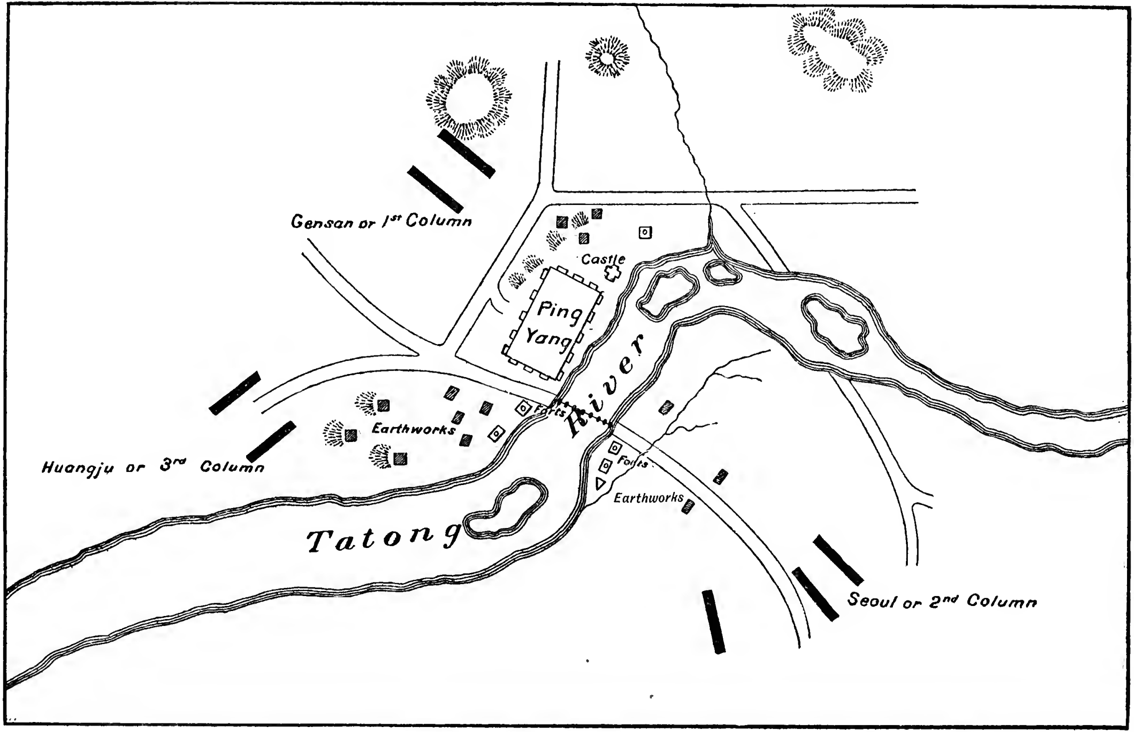
The work of the Japanese staff was complete. It left nothing to be desired, and it may be said of it, as has been said of the Prussian general staff, after which it is formed: "This body has become a real element of strength for their army, and has in a large measure contributed to their success, while gaining for itself a justly merited reputation." The Japanese leaders by their work have shown themselves to be models of the highest type of scientific warfare, and I believe that when the official account of this war shall have been written it will be found to have been fruitful in lessons upon the art of war. Already we find the English army at Aldershot practicing night operations with the field telegraph as a medium of communication between the advancing columns. Three brigades engaged in this manœuver on April 19 in presence of the Duke of Connaught, repeating the practice a little later with volunteer troops.

In no portion of that tremendous leap to civilization which Sir Edwin Arnold has called a quiet revolution, has Japan made greater advances than in her military department. Her ambition in the beginning of this remarkable transformation was to possess a complete army corps, armed, equipped, organized and drilled after modern ideas, with transport and supplies ready at all times for instant use, making her a valuable ally to be sought in any contemplated operations in the far East, thus giving her a voice in questions which might involve her interests. How far her aim has been attained may be judged if we realize that when the war began her military resources consisted of three lines of troops,—viz.: with the colors 62,425, first reserve 97,707, second reserve 109,987, total number of troops on war footing 270,119,—and that a combination of three great military nations was deemed none too strong to overawe this plucky little people, who only succumbed to their demands for want of an ally to stand by her side in the fight she was burning to make.

It seems hardly to be realized that a great military nation has been born, ushered into existence amidst the rattle of musketry, the booming of cannon—baptized with fire. This nation, displaying all the best qualities of a warlike people trained to arms, commanded by men who upon the land and upon the sea have proved themselves to be strategists and tacticians of the first order, must no longer be regarded only in the light of tea-houses, quaint art and gentle manners. When the smoke has cleared away, the effect of Ping Yang will be found hardly less violent and far-reaching than Königgratz and Sedan. Japan is at once the England and the Germany of the far East; she is invincible in her island home to any single nation that may come against her.



EASTERN CHINA AND COREA.


Gensan or 1st Column
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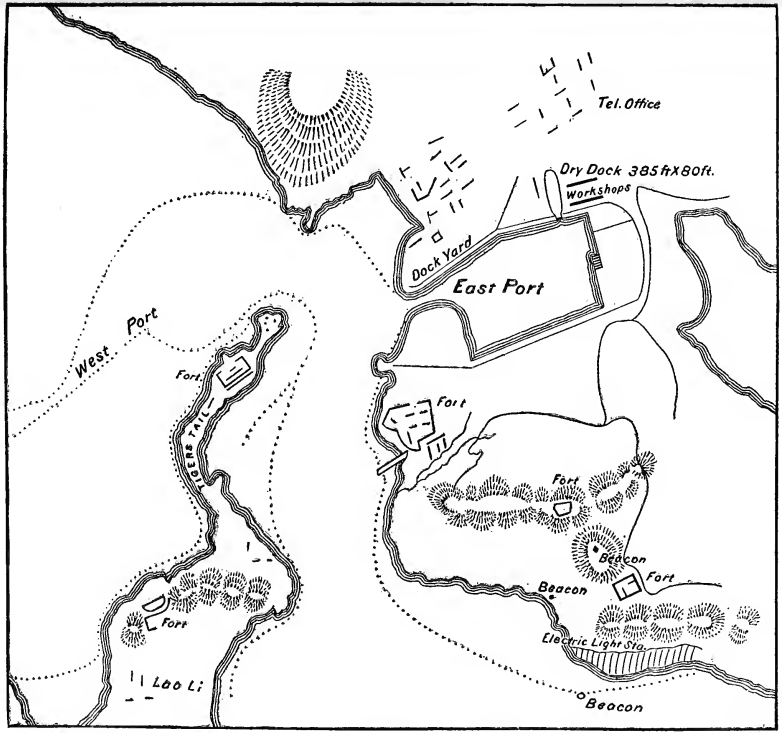
Huangju or 3rd Column
Tatong
Seoul or 2nd Column

PING YANG.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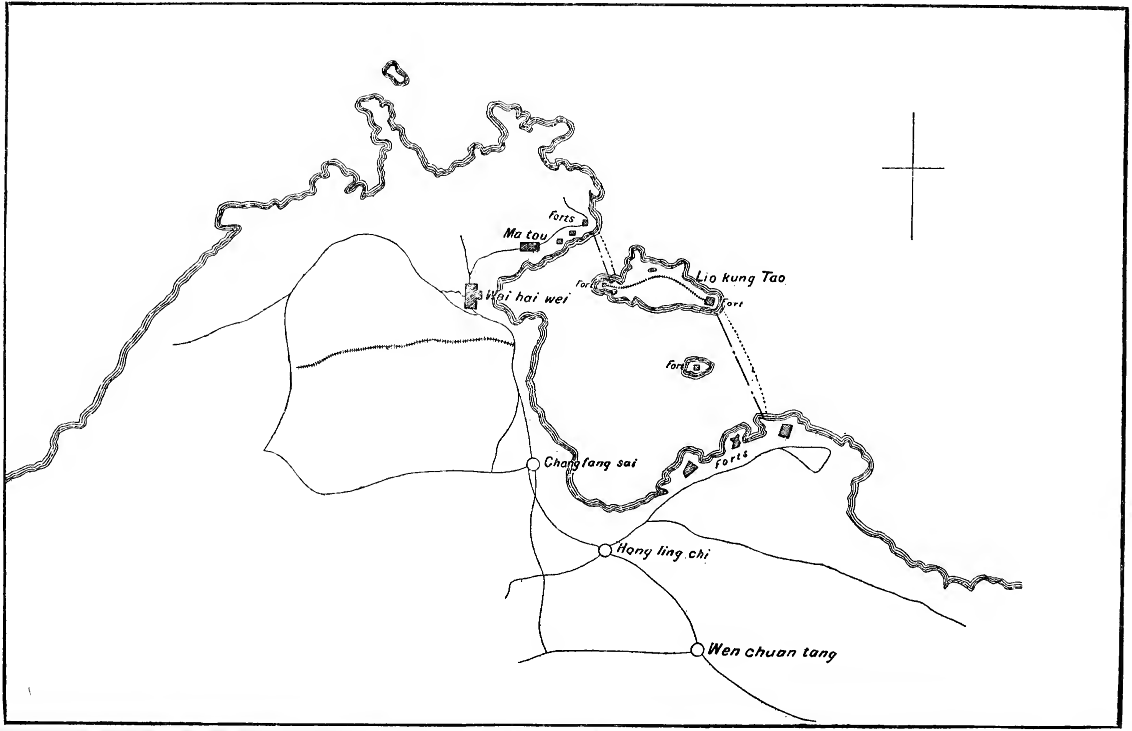
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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

POINTS SUGGESTED BY FLEET DRILL.

By Ensign F. K. Hill, U. S. Navy.

The following criticisms are suggested by our recent squadron manœuvres:*

Conning Tower.

The conning tower is the place from which the captain is to direct a ship's movements in battle; and, logically, he (or his representative) should be there during fleet manœuvres. If the bridge is used in peace (and it is only a peace construction), the officers who have charge will never have the same ready command of the many instruments placed in the conning tower as if they always managed the ship from the tower. To make the case more plain, consider the instruments which are found on the bridge of the U. S. S. New York. (*See list.*) Every officer of the line knows so well where all these instruments are that he can put his hand upon them on the darkest night. This is from constant practice; but, as he rarely enters the conning tower, and never has to use the instruments there, he does not know their location. Hence, if suddenly called to work the ship in action, he would simply be confused. All of our ships with which the writer is familiar have their conning towers so placed that they are almost useless; and, judging by their late war, the Japanese and Chinese were no better off; for the officers state that they could not manœuvre their fleets from the conning tower, and only sought it for safety when engaged at short range.

Closely connected with the manœuvring of the fleet, or ship, from the conning tower is the making of signals. At present,

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* North Atlantic Squadron.

as everybody acknowledges, we have no system of *war* signals; and no one in our navy, so far as is generally given out, has proposed any feasible scheme to remedy the present lack. Flags are worthless, yet we still have them. Shapes are proposed, but have never been tried. The writer suggests the following:

A conning tower higher than at present; *no peace bridge, no chart-house,* etc., above the conning tower; but concentric with it, a cone-shaped mast having at its base and immediately over the conning tower a room sufficiently large to manipulate such gear as will work shapes placed on a steel pole projecting from the top of the cone mast. This signal manipulating room should be protected (2″ steel) and in direct communication with the conning tower. On all large ships and battle-ships two of these conning towers and masts would be necessary, and should be connected by telephone. All the necessary instruments mentioned as being on the peace bridge should be placed in the conning tower, and habitually worked from that point.

Surrounding the conning tower, and on a level with it, a bridge should be placed so that the officer-of-the-deck would not be confined to the limits of the conning tower; and also such shutters should be furnished to the conning tower as might be kept open in ordinary cruising to give better sight and air to the helmsman within.

Now as to the Fleet.

Practically in all fleet battles of the future, the speed will be at least fifteen (15) knots; therefore fleet tactics should be carried on at that speed. The judgment and practice acquired by handling a fleet at a speed of nine (9) knots are almost useless when the speed is increased to fifteen (15). The times at which the guide ship (in such movements as "forward into line, left oblique") should go ahead full speed are different for different speeds. The helm angles differ, as do many other minor points connected with the proper maintenance of the exact bearings and distances of the various ships. Why should we learn to manœuvre at nine (9) knots when we will have to throw away practically all ideas gained when we go into actual battle, or shall have to run at a low speed, which will place us at a great disadvantage? Of course, the first few days of drill with a new fleet might be at a low speed for safety; but the speed should be rapidly increased until actual war speed is obtained.

Closely connected with the speed and manœuvring ability is the question of having the ships of a fleet as nearly as possible alike. Nearly every ship we have is slightly different from all others. Each one as it is built is the latest and best thing out, we are told. But would it not be better if we considered what ships are to do, and tried to make our fleets homogeneous? By this I do not mean that we are not to progress; but would it not be better to have some tactical unit, say four (4), and then let the vessels be built to form tactical units? Thus four (4) consecutive ships of a particular class would be exactly alike, built for a certain duty and station; and the next four (4) for some other duty and station, and so on. This would be particularly desirable in battle-ships, which remain at home and which should be grouped as a squadron and exercised together; so that when combined with another group of four (4) to form a fleet, there would only be a case of assimilating two (2) groups instead of eight (8) independent vessels, all of different characteristics. These groups of four (4) should all be exercised together when first commissioned, and then detailed to the same station, after which, with a certain amount of fleet drill at stated periods, they could be kept in a high state of efficiency. As an example of the results of such training of similar vessels, it may be stated that in the German navy they have units of torpedo-boats (seven (7) in a group) which are able to steam at full speed in echelon, while each vessel is in touch with its neighbors. Another argument for the group system is that if four (4) similar vessels are fighting together, the line of bearing on which any one can fight advantageously will be the same for all the others.

PERSONNEL.

The time that our admirals serve as commanders-in-chief is so brief that they hardly get into working condition themselves before they are either relegated to the retired list or go on some shore duty. The cause of this trouble is that the slowness of promotion in the line has caused our officers to pass a great length of time in the lower grades and but a short time in the command grade. We even go to the extremity of making commodores do admiral's work, calling them acting rear admirals and giving them commodore's pay.

This shows that we should have more officers in the upper grades, and that such legislation should be enacted as would cause the time spent in the various grades to be more nearly equalized than at present.

As an example of the bad results of the present condition of affairs, it may be stated that on the home station, where most of the fleet drills are expected to take place, there is an average of one (1) new commander-in-chief each year, with frequent cases in which the admiral remains in command for a few months only.

The commanding officers are not changed quite as often as the admirals, but even they frequently do not remain long enough to get the best results out of their respective ships. In addition to this, the commanding officers (or their representatives) do not handle their ships in fleet tactics as if in battle (for reasons stated in connection with the conning towers); and the writer, having served on five (5) of our modern cruisers, never knew but one commanding officer who went into the conning tower at great gun drill and from there controlled the battery; and even that one did not make a practice of going there.

The remedy for this is for the commanding officers to take their position during drill or gun practice in the place assigned them in battle, and from there to control the guns as if in battle: for certainly the captain should have drill and preparation as well as the divisional officers. After the captain has thoroughly drilled the ship, would it not be wise to imagine certain casualties, and allow the command to devolve on some of the other officers, giving each a turn, down to the lowest ensigns?

As for the watch officers, they always have their regular stations at drill and target practice, and are there as if for battle; and the only suggestion in regard to them is the one above, that they should succeed the captain in command and be drilled at his station.

There is but one test for all our exercises, viz., "Are they carried out as if in battle?" If they fail in that, they should be dropped or *changed* so as to stand the test.

LIST OF INSTRUMENTS ON BRIDGE OF THE U. S. S. NEW YORK.

1 telephone.
5 speaking tubes.

4 electric buttons.
4 annunciators.
2 speed indicators (electric).
2 speed indicators (mechanical).
1 revolution indicator.
1 helm indicator.
2 electric tickers for revolution indicators.
1 helm telegraph.
2 mechanical indicators for revolutions.
1 automatic push-button for fog signals.
3 push-buttons with clock attachments for automatic working of siren, whistle and search-light.
1 Ardois signal-box.
4 control stands for search-lights.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

TESTS OF SOUTHERN COALS.

By Lieutenant H. S. Knapp, U. S. Navy.

The Bureau of Equipment has prepared a publication giving the results of many steaming trials of different varieties of coal, domestic and foreign, made by naval vessels. Among them appear the results obtained by the Montgomery during the past winter, while she was engaged in testing Southern coals from the fields in northern Alabama and southeastern Tennessee. As these tests were all made by one ship under circumstances as closely alike as possible, and the coals all came from the same general locality, it may be of interest to publish these results in the Proceedings in a separate and more detailed form. They will be found below, largely in tabular form; but the remarks supplementary to the tabulated data are quite as important as those data themselves in forming a correct estimate of the steaming value of the different coals for naval purposes.

For each test the operators furnished, free of charge, 75 tons of the particular variety; in addition, enough more of the same sort was purchased to provide for raising steam and getting in and out of port, for working auxiliaries, and for possible contingencies, thus ensuring the full 75 tons for the test proper.

The tests were each made in three parts, at speeds of 135, 120 and 100 revolutions respectively, burning 25 tons at each speed. At the start the speed was gradually worked up to 135 turns; when running smoothly, with sufficient steam making, the test began. As soon as the first 25 tons were burned the speed was at once reduced to 120 turns, and the fires worked to give the necessary power, cutting off one boiler if possible. When the second 25 tons were consumed the speed was immediately reduced to 100 turns, and the boiler power manipulated as before, until the end of the test.

Before each test the engines were overhauled and the bearings adjusted. The boilers were also carefully overhauled and cleaned; the tubes were swept, and a thorough examination made inside and outside to discover signs of any injury that might have resulted from the use of the coal previously tested. Salt feed was used only as necessity dictated.

During the intervals between tests the ship lay at Mobile, in fresh, or brackish water, excepting in two instances. Once, between tests Nos. 3 and 4, coal was taken at Pensacola, where the ship was six days in port; again, between tests Nos. 7 and 8, the ship was on detached duty in Caribbean waters for a little over a month, but the stays at any one place were short, and the bottom was not believed to have fouled materially in consequence. In fact, the highest speed was attained at 135 turns on the last test made.

In the table the tests are numbered consecutively as they were made, and the remarks supplementary to the tabulated results are given by reference to the number of the test. The I. H. P. was determined from three sets of cards, one set taken at each speed after conditions had become permanent, and when running at the prescribed speed, if possible. The I. H. P. of the auxiliary machinery was estimated at 62 throughout all the tests. The speed and distance run were determined by patent log, checked by observation.

The Montgomery has three double-ended main boilers, designated A, B and D, and two single-ended auxiliary boilers, C and E, all of the cylindrical return-fire tubular type. The principal data concerning them are given below.

Diameter, all		11′	8″
Length	A and B	18′	
	D	18′	8½″
	C and E	9′	0½″
External diameter of tubes, all			2¼″
Length of tubes	A and B	6′	3¼″
	D	6′	7″
	C and E	5′	11¼″
Number of furnaces	A, B and D	4	
	C and E	2	
Greatest internal diameter of furnaces, all			44⅞″

Length of grates	A and B	86″
	D	89½″
	C and E	82¼″
Grate surface	A and B, each	84.28 sq. ft.
	D	88.32 sq. ft.
	C and E, each	39.70 sq. ft.
Heating surface	A and B, each	2734.79 sq. ft.
	D	2871.20 sq. ft.
	C and E, each	1318.65 sq. ft.
Greatest width of combustion chamber,* all		4′ 10½″
Greatest height of combustion chamber, all		7′ 0½″
Depth of combustion chamber	A, B and D	2′ 4¾″
	C and E	2′ 4″
Internal diameter of chimney		5′ 8″
Height of chimney above grate bars		60′

SYNOPSIS OF REMARKS.

Trial No. 1. Coal easily stowed. Requires considerable working to make it burn efficiently, as it cakes soon after slicing and makes a considerable quantity of clinker. Half of the fires require cleaning every watch, and tubes require sweeping every 36 hours. Fires were very dirty in 8 hours from the time they were started. Owing to dirty fires it was impossible to maintain 135 revolutions after the first three hours of trial. Showed lack of efficiency at high speed test. Formed great quantities of smoke. Good for blacksmith's use. No injurious effect observable on boilers.

Trial No. 2. Coal easily stowed. Requires moderate amount of working to make it burn efficiently; the amount of clinker was not excessive, but appeared to stick firmly to the grate bars and was difficult to remove. Owing to dirty fires it was impossible to maintain 135 revolutions after four or five hours. Tubes require sweeping every 36 hours. Formed great quantities of smoke. No injurious effect observable on boilers. By a mistake, not observed until too late, the test at highest speed was closed when only 23.46 tons had been consumed.

Trial No. 3. Coal easily stowed. Requires little working to make it burn freely, the clinker being small in quantity and easily removed. Revolutions easily maintained. Formed great quantities of smoke. Tubes require sweeping every 24 hours. During highest speed test flame issued continuously from both stacks, heating them and the uptakes to a dangerous extent; and sparks fell in great quantities on deck, making it necessary to wet decks

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* There is a separate combustion chamber for each furnace.

Consecutive number of Test.	Style of Company Furnishing Coal, and Name of Coal.	Part of Test.	Duration, in Hours.	Area of Grate Surface.	Boilers Used.	Fuel, in Pounds, Consumed per Hour.	Per Cent. of Refuse.	I. H. P. of Main Engines.	Fuel, in Pounds, Burned per I. H. P. per Hour.	Knots per Ton of Coal.	Speed.	Revolutions.			Knots Steamed.	Character of Smoke.	Hours Necessary between Cleaning Tubes.	Condition of Bottom.	Days out of Dock.	Wind.		Condition of Sea.	Estimated Effect of Wind and Sea on Speed.	Draught.			
												Starboard.	Port.	Mean.						Force, Beaufort Scale.	Direction, Degrees from Ahead.			Before Test.		After Test.	
																								For'd	Aft.	For'd	Aft.
1	Sloss Iron and Steel Co. "Sloss."	1st	10.65	296.58	ABCD	5258	11.16	2109.14	2.42	6.452	15.15	130.1	129.2	129.65	161.3	Grayish Black.	36	Good.	40	3-4	0-167	Smooth.	None.	13′ 9″	16′ 0″	12′10″	16′ 0″
		2nd	11.35	296.58	ABCD	4934		1491.90	3.175	6.584	14.5	119.6	118.3	118.95	164.6				41	3-4	135-90	Smooth to Heavy.	None.				
		3rd	19.	208.26	ABC	2947		1183.62	2.366	8 604	11.3	99 92	99.99	99 995	215.1				41	3-5	169-51	Moderate.	None.				
2	Tennessee Coal, Iron and Railroad Co. "Pratt."	1st	10.75	296.58	ABCD	4887	9.46	2318.82	2.06	7.216	15.56	132.49	132.43	132.46	169.3	Grayish Black.	36	Good.	50	3-2	128-15	Light Swell.	None.	13′10″	16′ 3″	12′ 6″	16′ 0″
		2nd	12.	296.58	ABCD	4667		1552.99	2.89	6.908	14.4	120.01	120.00	120 005	172.7				51	2-4	37-127	do.	None.				
		3rd	19.8	208.26	ABC	2828		936.55	2.88	9.436	12.02	100.11	100 02	100.065	235.9				51	5-2	107-25	do.	None.				
3	Mingo Mountain Coal and Coke Co. "Mingo."	1st	7.8	296.58	ABCD	7179	6 01	2371.87	2.95	4.88	15.61	135.07	135.53	135.3	121.8	Grayish Black.	24	Good.	65	1	......	Smooth.	None.	13′10″	16′ 4″	12′ 3″	16′ 3″
		2nd	11.2	296.58	ABCD	5000		1662.36	2.90	6.20	13.83	120.	120.	120.	154.9				66	1-2	135	do.	None.				
		3rd	18.5	208.26	ABC	3027		884.48	3 20	8.62	11.7	100.	100.05	100.025	215.5				66	2	135-0	do.	None.				
4	Tennessee Coal, Iron and Railroad Co. "Cahaba."	1st	9.5	296.58	ABCD	5894.74	7.0	2338.95	2.455	5.488	14.44	134.6	135 2	134.9	137.2	Dark Gray.	48	Good.	73	4-5	33	Moderate.	0.5 loss.	13′ 8″	15′ 8″	12′ 8″	15′ 6″
		2nd	12.2	256 88	ABD	4590.16		1737.75	2.550	7 072	14.45	120.	120 04	120.02	176.8				74	4-5	33-135	do.	None.				
		3rd	18.8	†168.56	AB	2978.73		864.33	3.107	8.988	11 96	99.99	100.02	100.005	224.7				74	2-5	120-55	Smooth to Mod.	None.				
				‡208 26	ABC																						
5	Standard Coal Co. "Milldale."	1st	9.5	296.58	ABCD	5895	8 94	2199.17	2.607	5.934	15.61	135 1	135.	135.05	148.4	Grayish	60	Slightly Foul.	88	3-4	120-140	Moderate.	None.	13′11″	15′11″	12′10″	15′11″
		2nd	12.	296.58	ABCD	4667		1744.34	2.584	6.536	13 6	120.2	120.1	120.15	163.4				89	5-6	11	do.	1.0 loss.				
		3rd	16.5	208.26	ABC	3062.8		927 46	3 302	8.644	11.8	100.	100.	100.	195.				89	4-6	11-180	Smooth to Mod.	None.				
6	Southern Jellico Coal Co. "Jellico."	1st	* 8.5	296.58	ABCD	5797.65	5.7	2249.60	2.508	5.879	15.21	135.17	135.	135.085	*129.3	Grayish Black.	60	Slightly Foul.	94	1	....	Smooth.	None.	13′ 9″	16′ 2″	12′ 6″	15′11″
		2nd	* 9.25	256.88	ABD	5054.36		1488.38	3.217	5 909	14 05	119.955	119.98	119.967	*130.				95	1	....	do.	None.				
		3rd	*15.05	168.56	AB	3277.34		928.35	3 309	8.077	11.8	100.05	100.004	100.027	*177 7				95	1	....	do.	None.				
7	Corona Coal and Coke Co. "Corona."	1st	7.5	296.58	ABCD	7466.66	16.69	2113.90	3 432	4.468	14.9	133.465	133.955	133.71	111.7	Grayish Black.	24	Slightly Foul.	108	1	50-150	Smooth.	None.	13′10″	16′ 2″	12′ 6″	16′ 2″
		2nd	9.75	296.58	ABCD	5743 57		1689.09	3.28	5,468	14.	120.08	120.04	120.06	136.7				108	1	150-90	do.	None.				
		3rd	14.5	212.30	ACD	3862.07		971.80	3.736	6.84	11.79	100.312	100.	100.156	171.				109	1	Var.	Smooth to Mod.	None.				
8	Pearson Coal and Iron Co. "Pearson-Warrior."	1st	9.03	296.58	ABCD	6222.22	9.36	2267.10	2.676	5.64	15.32	135.	135.	135.	141.	Dark Gray.	60	Slightly Foul.	155	2	22-75	Smooth.	None.	13′ 8″	16′ 8″	12′ 6″	16′ 6″
		2nd	11.97	256 88	ABD	4666.66		1800 75	2.505	6.52	14.5	120.	120.	120.	163.				155	3	45-68	Smooth to Mod.	None.				
		3rd	15.33	172.60	AD	3733.33		933.32	3.735	7.268	11 09	100.	100.	100.	181.7				156	4	26-149	Mod. to Smooth.	None.				
9	Virginia and Alabama Coal Co. "Coal Valley."	1st	7.75	296 58	ABCD	7225.80	10.02	1948.30	3 594	4.94	15.9	131.6	129.6	130.6	123.5	Dark Gray.	60	Slightly Foul.	162	1-2	15-117	Smooth.	None.	13′ 8″	16′ 8″	12′ 6″	16′ 9″
		2nd	9.	296.58	ABCD	6222.22		1366.42	4.356	5.66	14 05	120	120.	120.	126.5				163	2-4	29-117	Smooth to Mod.	None.				
		3rd	15.	168.56	AB	3733 33		962.32	3.645	7.124	11 87	100.	100.	100.	178.1				163	1-4	5-107	do.	None.				
10	Tennessee Coal Co. "Cripple Creek."	1st	8.25	296.58	ABCD	6787.87	10.75	2226.37	2.967	5.428	16.2	135.	135.	135.	135.7	Dark Gray.	60	Slightly Foul.	171	2-3	49	Smooth.	None.	13′10″	16′ 4″	12′10″	16′ 6″
		2nd	11.33	256.88	ABD	5090.90		1531.59	3.194	6.888	12 9	120.	120.	120.	172 2				172	1-4	11-56	do.	None.				
		3rd	16.66	168.56	AB	3360.00		944.39	3.338	7.600	11.4	100.	100	100.	190.				172	2-4	0-140	do.	None.				

† For 11 hours.
‡ For 7.8 hours.

* Only 25 short tons were furnished for this test, which was therefore made by burning 22 long tons at each speed. Correcting the column "Knots Steamed" in proportion of 25 to 22, the values will be 144.8, 145.6 and 199 respectively.

and boat-covers for safety. At the lower speeds neither flame nor sparks issued from stacks. The boilers were uninjured, but the turret smoke pipes and uptakes were warped so that two forward dampers could not be closed.

Trial No. 4. Coal easily stowed. Burns freely with a very little working, but when necessary to force the fires on account of limited grate surface it burns poorly, as it will not stand much working. Clinker is moderate in quantity, but adheres to bars and is removed with difficulty. Formed moderate amount of smoke. Tubes required no sweeping during test, and only moderately dirty after test ended. 135 turns were maintained without difficulty, and at beginning of 120-turn test fires were allowed to die out under auxiliary boiler; at beginning of 100-turn test allowed fires to die out under boiler D, but difficulty was found in keeping steam, and fires were again started under the auxiliary boiler C. No bad effects observable on boilers.

Trial No. 5. Coal easily stowed. Mostly fine coal, the lump not exceeding 15 per cent. Caked readily when thrown on fires and burned freely with moderate amount of working; the amount of clinker moderate and easily removed. Revolutions kept up without difficulty. Fires did not require cleaning in the first twelve hours, and after that one-third of the fires were cleaned every watch. Tubes did not require sweeping during tests, and were only moderately dirty at end of tests. Formed a moderate amount of smoke. Boilers uninjured by use of this coal. Low speed test was stopped by fog when 22.56 tons had been burned, and speed during second test was greatly reduced by wind and sea.

Trial No. 6. Coal readily stowed. Burned very freely, with little or no working to keep required pressure, and with the formation of very little clinker and refuse. Formed a considerable quantity of smoke. Tubes did not require sweeping during tests, and were in fair condition at their termination. No bad effects observable on boilers. Short tons were furnished, so tests were conducted with 22 long tons burned at each speed. After arrival in port, all three blades of port propeller and one of starboard propeller were found bent, caused by hitting sunken logs in Mobile Channel.

Trial No. 7. Coal readily stowed. Consists of about 20 per cent. fine coal, rest lump. During high speed test it was impossible to make required number of revolutions, the fires being very dirty. Coal would not make sufficient steam without working, and when worked great quantities of clinker were formed; clinker was easily removed. Necessary to clean fires four hours after test began, and one-half of the fires were cleaned each watch thereafter. Tubes were nearly closed at end of tests. Great quantities of smoke were formed. No injurious effect on boilers observable. Propellers in same condition as in trial No. 6.

Trial No. 8. Coal easily stowed, being mostly fine coal with not more than 15 per cent. lump. Burned freely with moderate working, and revolutions were maintained without difficulty. Clinker moderate in amount and easily removed. Tubes did not require sweeping during tests, and were not very dirty at finish. Smoke only moderate in amount. Boilers uninjured by test. Propellers in same condition as in trial No. 6.

Trial No. 9. Coal easily stowed, containing about 60 per cent. of lump. During high speed test it was impossible to maintain the required revolutions. The fires were very dirty after four hours. For efficient work half the fires would have to be cleaned each watch. Considerable clinker and a large volume of smoke formed. Tubes were not swept during tests, and were found moderately dirty at their conclusion. No bad effects were observed on boilers. Propellers as in trial No. 6.

Trial No. 10. Coal about 50 per cent. lump, some of the lumps very large; easily stowed after breaking up the large lumps. Burned freely with small quantity of clinker. The required revolutions were maintained without trouble. When fires were worked flames issued from both stacks, burning off the paint. Volume of smoke not excessive. Not necessary to sweep tubes during test; at conclusion they were only moderately dirty. Boilers uninjured by test, but uptakes and inner stacks were slightly warped by excessive heat. Propellers as in trial No. 6.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

ARMOR FOR SHIPS OF WAR.

By Professor P. R. Alger, U. S. Navy.

Before entering upon a discussion of the uses of armor and the considerations which should govern its distribution in ships of war, it will be well to briefly outline the history of its introduction and development and describe modern methods of its manufacture.

It was the introduction of shell-guns which rendered wooden walls, and even iron hulls without armor, impracticable for war vessels, and the signal instance of their effect in the annihilation of the Turkish fleet at Sinope first showed the necessity of providing some protection against their destructive fire. To John Stevens, of Hoboken, N. J., belongs the credit of originating the idea of applying armor to the sides of ships, but the French first gave this idea practical shape in the floating batteries which, on October 17, 1855, silenced the Russian forts at Kinburn. The cuirass of ancient times was restored, but instead of defending the breasts of single warriors from hostile spears, it was expanded over whole frigates—their armament, men and machinery, and thickened to resist shells and even solid shot.

But the superiority of the defense was short-lived, and the introduction of new weapons of attack and the continued advance of artillery in weight and power soon forced a corresponding development of armor.

For some years manufacture of armor was limited to plates of small area, and imperfect welds and steely spots, as well as great irregularity in quality, were necessary evils owing to imperfect appliances for the production of thick plates. Laminated plating, when tried, was found greatly inferior to the same thickness in a single plate. In 1859, however, armor manufacture had so far developed that French 4¾-inch plating proved superior to the attack of the 68-pdr., then the most powerful naval gun, and in 1860 the English report "vessels clothed in rolled iron plates 4½ inches thick are to all practical purposes invulnerable against any projectile that can at present be brought against them at any range." But the general adoption of rifled guns on the Continent and the introduction of the 11-inch and 15-inch smoothbore guns in the United States called for renewed exertions on the part of the armor makers, and in 1867, it being still impossible to produce plates of reliable quality more than 6 or 7 inches thick, the plate upon plate system, in which several thick plates were superimposed, was tried and proved superior, in the then state of the art, to the solid plate of equal thickness. In 1868 plates over 8 inches thick were tested, and in 1872 12-inch plates were tested both in England and Prussia, and, though of good quality, were hardly a match for the guns brought against them. Such had been the development of the artillery with which armor had to contend that while, as late as 1863, 4½-inch plating made a ship invulnerable, in 1868 it took 9-inch plating, and in 1872 a 12-inch plate was pierced on the firing ground. With the introduction of 12-inch plates the limit of regularity in manufacture with wrought iron seemed to be reached, and the cost of the plate upon plate system, owing to difficulty in making the plates fit each other, led to the trial and adoption of the sandwich system, in which layers of wood separate the two or more plates making up the complete target. The first application of this system was to the English ship Dreadnaught, whose turrets, built up of two 7-inch plates, separated by 9 inches of teak and secured to a backing of 6 inches of teak and two ¾-inch skin plates, were considered more than a match for the 12-inch rifle. But the advent of the 14¼-inch Krupp rifle in 1875 and the 81-ton Woolwich gun in 1876 marked the final supremacy of the gun. Wrought-iron armor had now reached its highest development in the Inflexible, whose armor consisted of two layers of 12-inch plates with 11 inches of teak between, backed by 6 inches of teak and two 1-inch skin plates. Simultaneously with the adoption of this armor disposition the Italian government, desirous of building the most powerful ships in the world, called for competitive tests of 22-inch armor, and two French and two English firms having submitted plates, in 1876 took place the famous Spezzia trials which revolutionized armor manufacture in Europe. The plates submitted were solid wrought iron, sandwich wrought iron, sandwich with wrought-iron face plate and cast-iron rear plate, and solid steel, the latter made by Schneider & Co. of France. The guns used were the 10-inch and 11-inch Woolwich rifles and the Armstrong 100-ton gun. The Italian commission condemned the types containing cast iron as of relatively feeble defensive qualities; stated that the remarkable advantages realized with the single plates left no doubt of the superiority of this disposition over the sandwich, and concluded that the most advantageous disposition of armor was embodied in the solid steel plate, this having kept out all shot, although wrecked thereby, while the iron targets were pierced by the shot from the 100-ton gun. Thin steel plates and iron plates faced with steel had ere this been tried in England with doubtful success, but it was now recognized that the day of wrought iron had passed, and attention was at once turned to the production of armor having the resisting qualities of the Schneider plate without its brittleness. In August, 1887, the first of what are known as compound plates was tested at Shoeburyness, England. This plate, made by casting a steel face upon a wrought iron back and rolling the whole to a thickness of nine inches, was tested with the 7-inch rifle, the penetration being but 3⅛ inches, whereas in a wrought-iron plate it would have been fully 8 inches. In another year 9-inch compound plates, now adopted for the Inflexible's turrets, resisted the 9-inch rifle, so rapid was the development of the new system, and in 1880 the manufacture of both compound and steel armor had so progressed that they were brought into close competition. In 1882 the Italian government again invited armor makers to submit plates to test in order to determine the best system for use on the Lepanto; and Cammel & Co. and Brown & Co., of England, the foremost makers of compound armor, and Schneider & Co., of France, the leading makers of steel armor, each submitted a plate 18.9 inches thick. Two shots from the 100-ton gun wrecked each compound plate, while the steel plate, after three, still covered the greater part of its backing, the commission concluding that the Schneider plate was superior to the compound plates and better adapted to protect a ship's side. Steel plates were not always victorious, however, for in several trials, notably that at Ochta, in 1882, the compound plate proved the better, and the less cost and more rapid development of this system in England led to its exclusive use there and its general adoption on the Continent during the next ten years. The demand for steel armor was, however, sufficient to continue its development, and its increasing superiority was so demonstrated by various tests that when the United States, in 1886, had before it the task of domesticating the manufacture of heavy armor, the decision as to the preferable material was not doubtful, and steel armor was ordered for all the armored ships then authorized by law. In 1890 the first public trial of a new material for armor—steel alloyed with nickel—took place at Annapolis, Md., a competitive test of a Cammel compound, a Schneider steel and a Schneider nickel-steel plate being held by the Navy Department. The compound plate proved inferior in a marked degree to the others, and the nickel-steel showed a remarkable resistance to cracking. In the same year a steel plate hardened on one face by a process of superficial carbonization was also tried at Annapolis and showed phenomenal resistance to penetration. In 1891 the U. S. Navy Department tested three plates made by the Bethlehem Iron Company of Pennsylvania by the usual forging process, and three made by Carnegie, Phipps & Co., of Pennsylvania, by rolling in a heavy plate-mill. Five of these plates were of nickel-steel and three had been surface-hardened, or Harveyed, as it was called, from the inventor of the process. This test demonstrated that good armor of moderate thickness can be made by the rolling process, a fact of considerable importance—that the nickel-steel plates made in the United States were markedly superior to any armor that had been publicly tested abroad, and that the process of surface-hardening offered a probable means, after some difficulties were overcome, of greatly increasing resistance to perforation.

As a result of these trials, our Government at once adopted nickel-steel Harveyized plates for the armor of all its ships, and within a very short time the use of surface-hardened steel, either simple or nickel, became general abroad, compound armor going out of use entirely.

The following is a brief description of the method of manufacturing armor used in the United States. The ingot, of approximately rectangular cross-section and about twice the weight of the finished plate, is made of open hearth steel, sufficient nickel being added to the furnace charge to produce about 3¼ per cent. in the final cast. After cooling, the ingot is stripped, reheated and forged to the required dimensions, the first operation being forging the upper end into a porter bar for handling, and the entire forging operation usually requiring several heats. Either an immense hammer or a hydraulic press may be used for forging, but the latter is considered preferable, both as regards manufacturing economy and superiority of product. The Bethlehem Iron Company have both a 120-ton hammer and a 16,000-ton hydraulic forging press; the Carnegie Company have a similar press and rolls, the latter being used at present only for thin plates (9 inches or less in thickness).

After forging, the upper end of the plate is cut off under the press or hammer, and the remainder, after cooling, is trimmed to size by a saw or planer. It is then placed in the Harveyizing furnace with its back and sides well protected by refractory materials and its face covered with the carbonizing mixture, is heated to a high temperature and allowed to soak for several days. When the hardening material has penetrated sufficiently into its face, the plate is removed from the furnace. It is then reheated, bent to the required curvature under the hydraulic press, again heated and allowed to cool slowly to remove the strains caused by bending. Occasionally, when the curvature is slight, plates are bent before being Harveyized; usually they are bent after Harveyizing, though before tempering. The Harveyizing operation merely consists in putting carbon into the face of the plate, and it is not until after the tempering process that this face becomes hard and brittle.

The next operation consists of heating the plate and chilling its surface with a spray of cold water, which hardens the highly carbonized face, but leaves the body of the plate still soft.

Finally the curvature is rectified under the press at a low temperature, not sufficient to soften the hard face, and the bolt holes are bored and tapped. The face of a Harveyized plate, after tempering, is so hard as to resist any tool, and when bolt-holes are required to be bored in the hard face for structural purposes an ingenious process of annealing, or softening, by an electric current has been devised and is in successful use.

Armor was first applied to wooden ships, but when iron and steel ships succeeded these it was found necessary to interpose a certain thickness of wood between the skin plating of the ship and the armor to decrease injury to the ship's side from impact of shot, and to provide a surface that could be trimmed to exactly fit the plates as manufactured. This backing is of oak or teak, and in modern ship design is usually of moderate thickness. At first much trouble was experienced with fastenings, the through bolts originally used causing leaks and snapping at the bottom screw-thread when the plate was struck. These defects were remedied by using bolts like wood screws extending not quite through the backing. The bolts now used are of forged steel, pass through the skin plating and backing and screw into the plate from two to three inches; they have shanks of reduced diameter to prevent breaking at the thread, are packed with hard rubber to prevent leakage around them, and have rubber washers under the nut heads. With steel armor one bolt is used to about every 4½ square feet of plate, and the diameters vary from 1½ inches for thin plates to 3½ inches for thick plates.

Whatever may have been the case in the past, it is safe to say that with the armor in present use wooden backing adds nothing to the resistance, and its only advantage is the supposed distribution of the shocks of impact over a large area of the plating behind armor due to the close fitting surfaces rendered possible by its use. It is to be hoped that the use of wooden backing will be entirely abandoned in future construction.

Putting aside for the moment the consideration of the increased resistance resulting from the surface-hardening processes now in general use, let us see what has been the outcome of the thirty years' development of guns and armor since 1860, when the 4½-inch iron plate was declared invulnerable to any gun afloat. To-day such a plate would be easily perforated by the projectiles of the 4-inch gun at 2000 yards' range, and at point-blank by the 6-pounder, and the best nickel-steel armor-plate must be almost twice the calibre of the gun attacking it in order to resist perforation at point-blank with normal impact and the best quality of armor-piercing shell. Even at fighting ranges the heaviest armor now in use will be no match for the 13-inch gun, provided the impact is nearly normal.

Five years ago the gun seemed to have finally and definitely attained supremacy, when suddenly and most unexpectedly the surface-hardening process was found practicable, and at once armor development appeared to take an immense stride forward. A 6-inch plate so treated has shown itself invulnerable to the attack of the 6-inch gun, a 14-inch plate to the 10-inch gun, and a 17-inch plate to the 12-inch gun. What is the cause of this change in the relative powers of attack and defense, and is the present relation likely to be an enduring one? I believe not. Years of development resulted in the production of forged steel shell which, being capable of withstanding the tremendous strains of impact upon steel plates without injury or practical distortion, delivered the entire energy of their blows upon the plates and pierced them. These projectiles, when called upon to meet the still greater strains of impact upon hard-faced armor, broke into fragments, dissipating a large part of their energy in heat and useless work, and consequently failed to penetrate. Only when their velocity was so great as to cause their broken fragments to tear through was the Harveyed armor pierced. But already we are perfecting our projectiles to meet the new demands, and there is no reason to doubt that in the course of time they will be produced of such a quality as to endure impact at high velocity upon the hardest surface. Experimental shell have been tested at the Indian Head Proving Ground which passed through Harveyed plates without distortion, and it has been shown, in my opinion, that with such projectiles the hard-faced armor is not greatly more resisting than the homogeneous nickel-steel armor it has superseded.

But if guns now overmatch all practicable armor, and continue to progress as they have in the past, more rapidly than armor, will not they, or even new weapons of offense now unknown, cause the use of armor for ships to be abandoned and become obsolete, as the invention of gunpowder drove out of use armor for men? This is a serious question, usually answered in the affirmative by civilians and often by military men, and merits consideration, for if armor is ever to be abandoned, now is the time for us to give it up and plan our new ships on other lines.

Two arguments are commonly advanced in favor of the opinion that armor for ships of war will, in course of time, become obsolete. The first is based upon the supposed analogy of the case of ships with that of men—since the development of small arms resulted in the abandonment of armor for men, why will not continued advance in the power of ordnance render it useless to armor ships? The answer is simply that the analogy is a false one; the strength of the individual is limited. while the carrying power of ships depends only upon their size and may be made as great as we please. Moreover, a man being far more highly organized than any work of human hands, is put "hors de combat" by a wound in any part of his body, and consequently must be completely covered with armor to be really protected; while a ship, over a very large percentage of her area, may be pierced through and through without suffering serious damage, and needs protection only over a few vital parts. Lastly, even if the power of guns were so great as to render it useless to attempt to keep out their armor-piercing projectiles from any part of a ship, still an enormous advantage would result from the use of armor which kept out explosive shell. A solid bullet is enough if it hits a man, but a great many solid shot of the largest size may pass through a ship without putting her out of action. A distinguished British naval officer in expressing his contempt for all sorts of pounders, from 18's to 68's, when firing solid shot, added, "but, for God's sake, keep out the shells," and his remark expressed the truth, learned from actual experience of war, that the highest and real function of armor is to keep out explosive shell.

The second argument against the continued use of armor for ships is that the approaching advent of the "high explosive shell" will render it worse than useless, the enormous masses of explosive to be hurled against ships by the guns of the future being sufficient to blow in their sides and destroy them without penetration of their armor. Now, that we can, to-day, throw large charges of high explosives from our ordinary guns and detonate them on impact I do not doubt, but what I do doubt and deny is the alleged effect of such detonations. In order to give projectiles sufficient flatness of trajectory to enable us to have any practical chance of hitting an enemy's ship, we must make their walls of considerable thickness to withstand the strains of firing, whether from powder guns or air guns, and the effect of the detonation of high explosives is so local in its character that when such shell strike against armor the result is the complete shattering of the shell with little or no other effect. On the other hand, if we make the shell strong enough to pierce armor, and use delay-action fuses to detonate them, the amount of the explosive which can be put into the largest shell is too small to do great damage. In fact, as far as the experiments we have thus far made go, powder shell are more destructive than those filled with other explosives, and the idea of blowing in the side of an armored ship by the explosion of a shell is, in my opinion, a fallacious one.

But even allowing that in time to come the best armor will not only be unable to keep out the solid shot of large guns, but also their explosive shell, still a little consideration will show that by keeping out projectiles of the lesser calibres armor will render service of immense value.

Taking, for example, the proposed battery of the new battleships, four 13-inch, four 8-inch, fourteen 5-inch rapid-fire and twenty-six smaller rapid-fire guns, and assuming the turret guns to be in use constantly, while the rapid-fire guns, mounted in broadside, are in use only half the time, and allowing that the rate of fire is once every five minutes for the 13-inch, once every two minutes for the 8-inch, three times a minute for the 5-inch, and four times a minute for the smaller rapid-fire guns, we find, by a simple calculation, that of all the projectiles fired in any period of time only $\frac{6}{10}$ of one per cent. will be of 13-inch calibre, $1\frac{6}{10}$ per cent. of 8-inch calibre, $16\frac{5}{10}$ per cent. of 5-inch calibre, and $81\frac{3}{10}$ per cent. of the smaller calibres. In other words, 3-inch armor will keep out at least $81\frac{3}{10}$ per cent. of all projectiles fired by one battleship against another, 6-inch armor will keep out at least 98 per cent., and 12-inch armor will keep out at least $99\frac{4}{10}$ per cent. When we consider the fact that most impacts will not be normal and that the range will usually be considerable, we may safely say that under any probable future conditions armor of about 7-inch thickness will keep out 98 per cent. of all projectiles fired against it.

Assuming, then, that it is at least probable that armor will continue in use indefinitely on ships of war, let us consider somewhat how it can be distributed to the best advantage.

The displacement, and, consequently, the weight-carrying capacity of ships, being limited by practical considerations of expense and handiness, it is apparent that a defensive covering of even moderate thickness cannot be spread over their entire area, but that it must be limited to those portions of each ship which it is of vital importance to protect. It is of the first importance to preserve the stability of a ship by preventing such extensive water-line damage as to cause her to sink or capsize. Next in importance is the protection of the propelling machinery. Lastly, the offensive weapons of a ship, her guns, with their machinery and crews, must be as far as possible guarded from injury. With all power of offense destroyed, a ship may be saved, if her stability and propelling machinery are intact; with offensive weapons powerless and machinery disabled, the crew at least will escape destruction, and the fortunes of war may even cause the rescue of the ship herself from the hands of the enemy, provided she continues to float; but a sufficiently effective attack upon the stability of a ship must result in a total loss of ship, crew and all.

I do not mean to imply that floatability is to be absolutely assured first, then safety of the propelling machinery, and, lastly, that of the battery; this is a question of relative protection only. What I mean is, that in distributing our protection we should endeavor to, *first*, make it unlikely that our ship will be sunk in action; *second*, make it unlikely that her motive power will be destroyed; *third*, make it unlikely that her offensive power will be greatly weakened. The bigger the ship, the more unlikely all three should be. As to the prime importance of preserving floatability I think there can be no question, but the relative importance of motive and offensive powers seems somewhat doubtful. A total loss of manœuvring power is extremely unlikely under any circumstances, on account of the subdivision and under-water position of propelling machinery; but so also is the complete silencing of the battery very unlikely. When, however, we consider the fact that in the past ships have always been defeated by the reduction of their offensive powers, due to destruction and demoralization of their personnel, I think it fair to conclude that, although a *moderate* protection of motive power is only second in importance to the protection of stability, yet, after this is assured, then the protection of the guns and their crews becomes the more important. It must not be forgotten that there is an essential difference between the case of a whole ship, with men and machinery distributed throughout its length, and the small turret or casemate into which the vitality of a ship is crowded. "It is the thin line instead of the close column." In the modern battleship, where the offensive power is practically concentrated in *two* gun positions, it is more important to prevent any projectile from entering these spaces than it is to protect the whole length of the machinery space. If a projectile enters the turret it will probably put out of action, practically, one-half the ship's battery, but many projectiles may enter the machinery space without destroying the motive power. Moreover, the propelling machinery—boilers, engines, shafting, screws and rudder—being almost entirely below the water-line, the armor which is applied to the protection of the stability serves a double purpose, protecting the machinery as well.

Leaving out of consideration the class of so-called protected cruisers, in which an armored deck, flat amidships and sloping off on either side and at both ends below the water-line, affords the sole protection to the machinery, we find in almost universal use in armored ships a heavy armor belt, partially submerged, and of length varying from half that of the vessel to her complete length. This belt is usually composed of tapered plates, the below-water parts thinner than those above, and the plates becoming thinner as bow and stern are approached. When the belt is not complete an armored deck is fitted, sloping down forward and aft from its ends, which are connected by thwartship bulkheads.

The armor protection for the offensive weapons consists of turrets and barbettes, with ammunition supply tubes, and of casemates.

Besides the above, guns in the open are usually fitted with light shields, and the between-decks portions of the smokestacks are sometimes armored.

There being but a limited weight of armor allowable, it is evidently a question of great importance to properly proportion it so that the most advantageous distribution of the protection may result. Yet when we examine the plans of armored vessels built or building in our own and foreign countries, we cannot fail to discover that in many instances this important subject has been given too little consideration. When, for example, we see ships so designed that they will probably go into action with their armor-belts completely submerged; when we see them with heavy armor about the gun supports and with less, or even none, to protect the guns and their crews; and when, the most frequent of all, we see what may aptly be called "fictitious protection," such as thick conning towers which the impact of a heavy projectile would tear from their flimsy fastenings, and heavy armor plating of so little width that it would yield by being split long before it was pierced, then it becomes apparent that the subject of the proper distribution of armor protection needs discussion.

The following are the principles upon which I believe the armor distribution of battleships should be governed, with the arguments in favor of them.

(1) The *position* of the belt should be fixed with reference to the deep-laden draft of the ship, not her light draft. The practice of placing the belt with three-fifths or two-thirds below water at what is called normal draft is bad, because when a ship goes into action she will probably be laden down with extra ammunition and carry every pound of coal possible. Everything tends to sink your belt lower, and, if too low, you cannot raise it, but if too high you can always sink it to the proper place by letting in water.

The width of belt we have adopted for our battleships is 7′ 6″, and hitherto we have placed the belt so that at what is called "normal," but is really "light" draft, the upper edge is 3′ 0″ above water. Now the Indiana and class, with bunkers full (1640 tons of coal), draw 27′.15, or 3′.15 more than when at so-called normal draft (400 tons of coal). Consequently, if they go into action with bunkers nearly full and no other excess of weights, their belts will be only 1′ above water. But when their turret guns are trained to one side a heel of 3° results, and this will submerge their belts nearly a foot on the engaged side. In the new battleships balanced turrets will be used, and, consequently, there will be no heel due to training the guns; but it is proposed to place the belt 3′ above water at light draft (500 tons), which would put it only 1′ 6″ above with full bunkers (1300 tons). The Bureau of Ordnance wishes to raise the belts 1′, so as to be 2′ 6″ above water at heavy draft. The real questions are: 1st, What is the best position for the belt when the ship goes into action, and, 2d, what will the draft probably be when the ship goes into action? Now it seems to me that to have the belt 2′ 6″ above water and 5′ below is better than 1′ 6″ above and 6′ below, but in any event, having once decided on the best position with reference to the water-line, then we should place the belt so as to be in that position when the ship is *deep*-laden, for she is much more likely to go into action deep-laden than light, and being light she can be sunk deeper by admitting water to her double-bottom compartments, increasing her stability at the same time; whereas, being deep, she cannot be lightened.

(2) Belt armor should be thick enough to keep out all explosive shell. This will probably require a thickness equal to the calibre of the largest guns brought against it. Over the machinery space it should be of uniform thickness or very slightly tapered. Great taper weakens a plate in greater proportion than the saving of weight. Complete belts are not specially necessary, for the ends of the ship will get few hits compared with the central portion; there is little to protect at the ends, and water-line damage there is of comparatively small importance. The width of the belt should be at least seven times the calibre of the largest gun likely to be brought against it. The new English battleships (Magnificent class) are to have only 9-inch side armor, but I think this hardly sufficient. Our 13-inch common steel shell will carry a bursting charge of 60 pounds through that armor if they hit normally.

(3) The heavy guns should be protected by turrets and their supports by barbettes. The thickness of the turret armor should be greater rather than less than that of the barbettes. Both should be thick enough to keep out explosive shell, but the turret should, if possible, be thick enough to keep out all projectiles. The armor around the guns should be thicker than the side armor, because the turrets are more likely to be hit than the belt, since they always offer themselves to normal impact whatever the enemy's position, while the belt will practically always be at an angle to the line of hostile fire, and since the effect of a projectile which gets into the turret is likely to be far more serious than one which gets through the belt. A solid shot through the side or barbette armor is extremely likely to do no further damage; it will probably put a turret out of action.

The following examples may be cited as illustrating this. At the battle of the Yalu the Itsukushima was struck by a 21 cm. (8-inch) shell, which passed through the coal bunkers containing 30 tons of coal, about 12 feet thick, through a ½-inch bulkhead, and exploded in the engine-room gallery, a space about 15 feet square. Six large fragments passed through the port bulkhead, making holes one foot in diameter, and numerous smaller fragments passed downward into the engine-room, killing one and wounding another man, but doing no other injury. A 6-pounder shell exploded in the engine-room of the Hashidate without doing any injury. Either of these projectiles exploding in a turret would almost certainly have done serious damage.

(4) Ammunition tubes, or other means of protecting ammunition in transit from magazine to turret, are worse than useless except in the case of the heaviest guns, where any damage to the mechanical hoists would put the guns out of action. Whenever ammunition can be hoisted by whip, a clear passage, with no enclosing walls, is the best. Many of our ships are designed with ammunition hoists enclosed by steel tubes from one inch to two inches thick. A projectile striking one of these tubes would almost certainly bulge it in or distort it so as to completely shut off the supply of ammunition. Whereas, if there were no tube, the projectile could, at worst, cut the whip or other hoisting apparatus, a damage easily repaired, or, as a remote possibility, strike the ammunition in transit, an occurrence not likely to result in any serious consequences.

(5) Heavy conning towers, also, are worse than useless. The impossibility of getting a commanding view from such a station would certainly prevent the captain of a ship from occupying the conning tower in action. I would suggest a moderately thick armor plate, placed fore and aft, and well braced from each side, as a shield, on either side of which the commanding officer might stand. A speaking-tube, with a branch on each side of the shield, and leading to a distributing chamber below, would afford a convenient means of communication to all parts of the ship, the captain's orders being received at the central station and thence transmitted as required. Perhaps an armored well below the bridge would serve even better, orders by word of mouth being there heard and distributed by voice-tubes or telephones.

(6) The secondary battery of 4-inch or 5-inch rapid-fire guns should be in an armored casemate between the main turrets, and should be protected by at least four inches of armor. This thickness will keep out most explosive shell and all projectiles from small rapid-fire guns.

(7) Between the casemate, or armored superstructure, and the thick armor belt is a wide space which it is now usual to protect against explosive shell by the use of 4-inch or 5-inch armor. I have some doubts as to the advisability of this practice. Certainly the Indiana class and the Iowa designs, where four inches

of armor is applied over this space, while the casemate is unprotected except by 4-inch sponsons where the guns are mounted, are not good. Much better would it have been to have used this weight of armor for a complete covering of the superstructure.

In the new battleships where the superstructure has 6 inches of armor all over, it may be very well to cover the space above the heavy belt with 5-inch armor, but I am inclined to think that an addition to the height of the thick belt would be better.

As an example of armor distribution, the following table of weights for the Indiana class and the Iowa may be interesting:

	Indiana.	Iowa.
Protective deck,	534 tons	562 tons
12-inch and 8-inch gun positions,	1556	1440
Side and bulkhead,	1085	1045
Protection to secondary battery,	38	39
Conning tower and tube,	55	56
Cellulose,	55	65
Bolts and backing,	201	168
Total weight for protection,	3524	3375
	3375	
	149 tons difference.	

It is curious to note the difference in these designs, and, from my point of view at least, the sacrifice of real to apparent advantages in the latter design.

The Iowa, with the same coal supply on board, is of 700 tons greater displacement than the Indiana; she carries 149 tons less armor (2 inches less on her barbettes and 4 inches less on her belt), and she has 12-inch guns instead of the 13-inch of the Indiana, and, as a result of these great sacrifices, she can steam one knot faster. In order to add a knot to her speed she is made 700 tons larger and her offensive and defensive powers are greatly reduced. The curious arguments made in favor of the Iowa design were: 1st, "Progress in ordnance had resulted in such an increase of the power of guns that the only moderate calibres were now necessary to overcome any armor," and, 2d, "The recent developments in armor manufacture had resulted in such an increased power of resistance that it was safe to reduce its thickness." We had succeeded in making our guns so powerful that they were irresistible, and our armor so strong that it could not be overcome.

Fortunately, wiser counsels now prevail and the new battleships are to have 13-inch guns, and, in any event, a better armor distribution than we have had before, though the exact arrangement is still in doubt. The following table gives the approximate distribution of armor weights:

Protective deck,	556 tons
13-inch and 8-inch gun positions,	1600
Side and bulkhead,	1083
Protection to auxiliary battery,	381
Conning tower and tube,	57
Cellulose,	60
Bolts and backing,	235
Total weight of protection,	3982

It will be observed that, practically, all the additional weight of armor, about 400 tons, is to be devoted to the protection of the guns and personnel.

When we consider the armoring of ships smaller than the battleships, another problem presents itself. Only a moderate amount of protection can here be given, and, at the same time, only guns of medium calibre will be found on an enemy of the same class.

On the assumption that such ships will be armed with either six or eight 8-inch guns in turrets, and with a large number of 5-inch rapid-fire guns in broadside, which would be the most effective battery for use against another lightly-armored ship, we have to consider how to protect such a battery, and what the relative importance of the protection of stability, propelling machinery and battery is in such a ship. On the New York and Brooklyn we have devoted almost all our armor weight to a protective deck six inches thick on the slope, a belt four inches thick covering the middle length of the water-line, the 8-inch guns being in turrets of about 6-inch thickness, and the rapid-fire guns having nothing but shields.

This seems to me an unsatisfactory distribution. Would it not be better to trust to the armored deck with cellulose and coal above it for protection both to stability and machinery, and give 4-inch protection to the battery deck? At present, a sufficient number of 6-pounders on an enemy would make the New York or Brooklyn's gun-deck untenable, while their machinery is reasonably safe against the guns of a battleship. An armored cruiser may have to fight a battleship, but her main object is to exceed in power other armored cruisers, and this can only be when her defensive powers are not only proportioned to her offensive, but when they are properly proportioned among themselves.

And now, in conclusion, I wish to say a word about the importance of large calibre in the attack of armor. You may go on increasing velocities and improving projectiles as much as you please, but you can never get the terrible destructive effect of the large shell from a small one. This is so in the case of explosive shell, but it is even more so with armor-piercing shell, which are practically solid shot. The cracking and shattering effect upon the armor plate and the tearing, splintering and rending of the structures behind armor produced by big shell must be seen to be appreciated. There are many advocates of the restriction of calibre of naval guns to 12-inch, or even 10-inch, and you often hear it said, or read in books and papers, that the "best naval opinion" is for keeping down calibre. I beg of you not to believe this. The circumstances of actual fighting at sea add immensely to the effectiveness of armor and reduce greatly the power of guns in comparison with their relative values on the proving ground. The 13-inch gun is necessary for our battleships, and it is a concession to prejudice that restricts calibre to that size. The increase of one inch from 12 inches to 13 inches seems small, but it means an actual increase of energy of one-third, and a sight of the results of firing the 12-inch and 13-inch guns at the same plate would convince any one of the great value of this increase. Happily it has been settled that the new battleships are to have the 13-inch guns and not the 12-inch, and I do not hesitate to predict that if we ever have a naval war with a first-class power we will rather regret not having installed larger guns than the reverse.

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THE TURRETS OF THE NEW BATTLESHIPS.

By Ensign Joseph Strauss, U. S. Navy.

The armament for the new battleships 5 and 6 has been the subject of so much discussion that it would probably be of interest to the service to give the reasons why the novel arrangement of double turrets has been adopted.

For technical and structural reasons, economy of weight, etc., it has now become the general practice of battleship designers all over the world to arrange the principal guns of the ship, whether they are 10, 12 or 13-inch, in pairs in two turrets or barbettes, one forward and one aft on the centre-line of the vessel. With this arrangement of the principal guns decided upon, the question then arises: How place the guns of lesser size and importance?

Naturally, a commander would manœuvre his vessel to bring all of his principal guns to bear on the enemy, and this result can only be obtained by bringing him to bear on points between the quarter and the bow; that is, generally speaking, on the broadside. He can fire the forward pair ahead or the after pair astern; but only in the arc above stated can his entire principal battery be brought to bear, and it is this fact that induces an arrangement of the subsidiary battery that will give it its greatest importance when the enemy is on the broadside.

The arrangement of battery in the Indiana class followed the recommendation of the Policy Board, and later the Russians laid down the Petropavlosk class, which were almost identical in arrangement with the former. It is unquestionably a heavy battery with good command of fire, but has the one fault of having four 8-inch turrets, but two of which can be fired at the same enemy; two turrets must always mask the other two, and when weight and space are so valuable, any arrangement that will do away with this wastefulness should certainly receive careful study and consideration.

A reference to Fig. 1, which represents a plan of the Indiana, giving the position of her turrets, will show that she can deliver the fire from four 13-inch guns and four 8-inch guns at a target on the beam. She can fire two 13-inch guns and four 8-inch guns *dead ahead;* but to bring all of the latter guns to bear, the target must not be much off the midship line; for although the 8-inch turrets are arranged to fire 15° across the bow, it is extremely doubtful if the blast from their guns would not seriously injure the people in the 13-inch turret, situated but little below the axis of the 8-inch guns, and then directly in the line of fire.

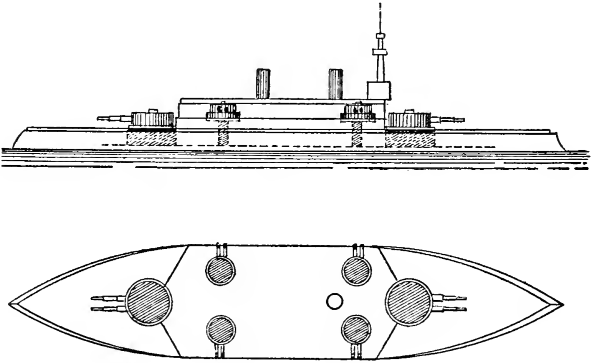

FIG. 1.

It may be said, therefore, that the Indiana's fire consists of four 13-inch guns and four 8-inch guns on the broadside, and (practically) two 13-inch guns and two 8-inch guns ahead, leaving out of consideration in this discussion the minor battery.

Fig. 2 shows an arrangement by which the two superfluous turrets are gotten rid of at once and the weight of fire kept the same; and were it not for certain objections which I shall cite, would be an easy solution of the problem.

1. The main force of the blast from the 8-inch guns comes directly over the 13-inch turret. It has been proposed to obviate this by an inch plate two feet above the roof of the latter. This

plate would have to be so well supported, however, that the view of the men at the sighting-hoods would be seriously interfered with. Experiments at Indian Head have demonstrated this. But, however well it is supported, it no longer affords protection to the men when the 8-inch turret is trained on the bow. The blast-plate is also likely to imprison the smoke from the 8-inch guns and interfere with the view of the men at the 13-inch sighting-hoods.

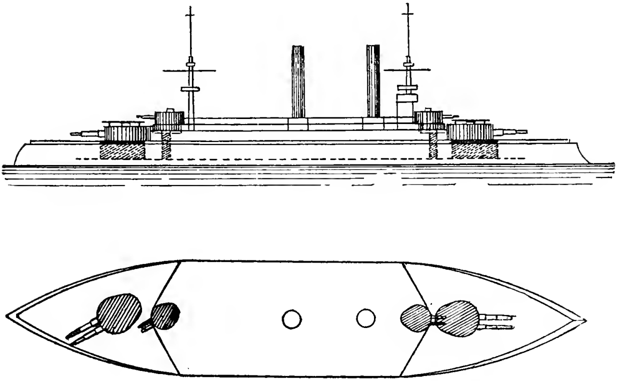

FIG. 2.

2. The area of the superstructure is seriously reduced and the space for boats, hammocks, chests, ventilators, hatches, etc., impaired. The length of the engine-room and fire-room spaces is also very much shortened.

3. The men at the forward two rapid-fire 5-inch guns on each side are subjected to an uncomfortable if not dangerous blast when the 8-inch guns are fired abaft the beam.

Fig. 3 shows a second solution of the problem; that is, of superposing the 8-inch turrets over the 13-inch turrets. It is this plan that has been adopted, and it will be seen at once that none of the objections incident to plan 2 obtain in this case, besides which many additional advantages are gained.

The first objection that naturally occurs to one in considering this plan, is "putting too many eggs in one basket." That is, should the 13-inch turret become jammed, or its rotation otherwise interfered with, the 8-inch guns of that turret would also become useless. This is true, but it is less the basis for an objection than appears on the face of it; for we have now entirely dispensed with one set of rotating gear, including engines, rollers, roller-paths and turning-tube, and the chance for disablement which otherwise rests on the poorly protected turning gear of the 8-inch turret is now, if not eliminated, transferred to that which obtains with the thoroughly protected turning gear of the 13-inch.

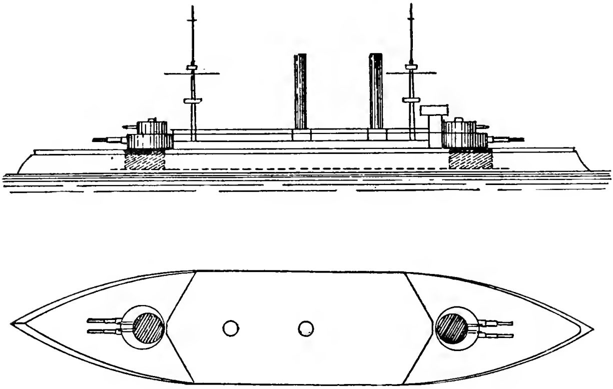

Fig. 3.

The great concentration of weight in the ship is another objection which has been urged. This objection is without foundation. The entire weight of one double turret, including guns, armor, framing, turret equipment, barbette-armor and turning engines, in fact everything that belongs to that part of the battery except the ammunition, will weigh in battleships 5 and 6, 947 tons. The weight of a 13-inch emplacement in the Indiana class exceeds this by 40 tons; and in the British Victoria the weight exceeded even that by at least 200 tons.

Complexity of ammunition supply was thought to be a hindrance to the successful mounting of guns on this plan. A glance as Fig. 4 will show how simply this part of the scheme is carried out. *A* is the handling room for the upper turret, and *B* for the lower turret. Their respective ammunition rooms are situated just outside of the handling rooms. The car in *B* is loaded with shell and powder charges and in one sweep is carried up by either hydraulic or electric power, with an alternative of hand-power in each case, directly to the rear of the 13-inch gun, and each section rammed home. The entire track rotates with the turret. In the same manner the 8-inch ammunition is hoisted to the rear of the guns in the upper turret, and runs *through* the lower turret, between the big guns, occupying no otherwise useful space in the latter, and, being enclosed in a small chute, its passage in no way interferes with the operations going on in the lower turret. Every gun can be loaded in any position of train, and the operation of each ammunition hoist is as independent as if situated in a separate turret.

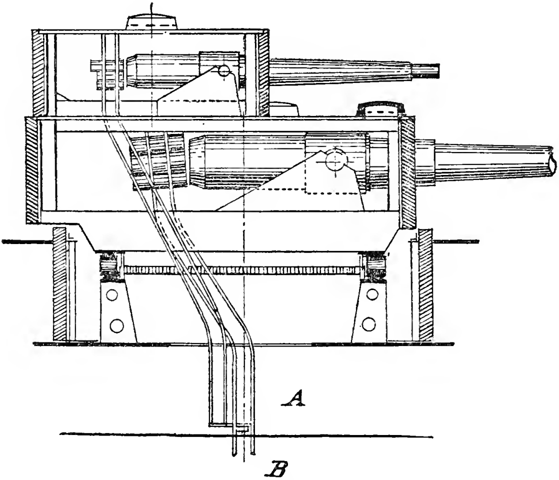

FIG. 4.

There is no communication between the two turrets other than through voice pipes, if that is thought necessary, and the two being separated by a 3-inch armor plate, no fragments from the upper turret can by any possibility lodge in the machinery of the lower and disable it.

The only objection on tactical grounds that has been made against this system is, that it might be desirable to fire the 8-inch guns at one part of the enemy's ship and the heavier guns at some other part of the vessel where the protection is heavier. This is not an objection when one considers how small a target the largest ship presents when distant any reasonable fighting range. To make the most hits some one point must be chosen to fire at, and this point is undoubtedly the middle of the ship. The heavier shots may occasionally be wasted on thin armor, and the lighter ones strike harmlessly on the heavy belt or turret armor of the opponent; that the opposite result may obtain belongs to the chance of battle, and its probability would be lessened were any attempt made to tell off guns for different duties. At very close range the work of the heaviest guns would be in attacking the belt and turrets; this does not prevent the lighter guns being directed against the casemate, or even trained against the unarmored ends, as the latter can be fired two or three times while the former are being loaded. It takes but thirty seconds to train the turret from starboard to port, and a heavy fire could be maintained against a weak enemy to port while the 13-inch guns were being prepared for delivering their blows against a stronger enemy to starboard.

Turning to the other side of the question, we will find that the advantages arising from this system are much more certain and well defined.

1. We have gotten rid of two complete turrets, their handling rooms, magazines, shell rooms, operating machinery and crews, with little or no loss of effective gun-fire. In the case of the Indiana the weight saved would have amounted to 320 tons.

2. We have dispensed with the barbette armor, turning tube, turning engines and framing for substructure of two more turrets, which saves an additional weight of about 140 tons, making a total saving of 460 tons.

3. The ammunition supply of the two upper turrets is now protected with 15 inches of armor, whereas in the Indiana class the ammunition supply is unprotected. It is almost impossible to adequately protect this important part of the battery, and it must be counted as an immense advantage when this can be made secure without the addition of a pound of weight. In all this saving of weight we are permitted to increase the armor shielding the 8-inch guns, and this in the adopted design has been done.

The turrets are to have 11 inches of armor in front and 9 inches in the rear.

4. Best possible command. The principal battery is reduced to two impregnable gun emplacements. The commander will need only to manœuvre his ship to bring these to bear—a most important consideration when one takes into account the many vital duties devolving on him in the heat of battle. He need not stop to consider whether the fire from one gun is going to injure the crew of another. This latter is a point that has not received the consideration in designing ships here and abroad that it deserves. A glaring example of this fault is found in the French battleship Brennus, where a system of bugle calls has been adopted by which one or more gun's crews must desert their guns and seek cover from the blast of some heavy gun that is about to be fired.

5. More space for secondary battery. This has been touched upon before, and it is only necessary to state that at least four more 5-inch guns can be efficiently mounted than when the turrets are separate.

6. Simplicity. In line with the great simplicity that is accomplished, a concentration of fire may be produced that would be impossible with any other scheme. One man trains four guns, and his sole duty is to keep the target " on " under the direction of the commander. At each gun of the four a man is stationed to look out for the elevation, and when that is attained, the guns may be fired, separately or together.

7. Smaller target. Not only is the vulnerable target area reduced 22 per cent., but concentrating it at two widely separated points provides a distinct advantage—that of removing the main battery from the region of the most hits.

The advantages of the arrangement of battery that has been adopted have been set forth without any attempt to place them in the order of their importance. From one point of view the great saving in weight could be placed first, involving, as it does, decreased draught, or increased coal supply or heavier armament; from the point of view of the captain who is to handle these ships in battle, the absolute control and simplicity are alone a sufficient warrant to depart so radically from former methods.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE NAVAL MILITIA MOVEMENT.

By Lieutenant A. P. Niblack, U. S. Navy.

Historical and Otherwise.

A brief review of the Naval Militia movement will show how it has grown out of an endeavor to create a national naval reserve of men and ships for war purposes, and how the original intention has been more or less modified in favor of local or State organizations of citizens of aquatic tastes rather than those of the strictly sea-faring class.

Historically, the first step may be said to have been taken by the introduction by Senator Whitthorne of Senate Bill 3320, on February 17th, 1887: "To create a Naval Reserve of auxiliary cruisers, officers, and men from the mercantile marine of the United States." This measure did not become a law, but as a result the Navy Department in 1887 prepared a plan of organization for a Naval Militia force based on a battery of 80 petty officers and men as a unit. On January 4th, 1888, Mr. Whitthorne introduced a bill (H. R. 1847) for which, on June 26th of the same year, he substituted H. R. 10,622, "To provide for the enrollment of a Naval Militia and the organization of naval forces." It made it lawful in States and Territories bordering on the sea and lake coasts or navigable rivers to enroll and designate as the Naval Militia, all sea-faring men of whatever calling or occupation, and all men engaged in the navigation of the rivers, lakes and other waters, all persons engaged in the construction and management of ships and crafts, or any part thereof, upon such waters, together with ship owners and their employés, yacht owners, members of yacht clubs, and all other associations for aquatic pursuits, and all ex-officers and former enlisted men of the navy. The limits of age were between eighteen and forty-five. The bill contemplated a naval reserve artillery and a naval reserve torpedo corps, the battery to consist of not less than four officers and eighty petty officers and men as the unit of the naval reserve artillery, and the crew to consist of not less than one officer and sixteen petty officers and men as the unit of the naval reserve torpedo corps. This measure did not become a law, but was the basis of State action in several States.

The Legislature of Massachusetts passed an act which was approved May 17th, 1888, establishing "A Naval Battalion to be attached to the Volunteer Militia." This was really the pioneer measure in the United States, but the organization under it was not completed till March 25th, 1890. The State of Pennsylvania, under an act approved April 26th, 1889, made provision for the establishment of not less than four companies "to constitute a Battalion to be known as the Naval Battalion of the National Guard of Pennsylvania." On the same day the Legislature of Rhode Island "established a Naval Battalion to be attached to the Rhode Island Militia." The Legislature of New York passed an act, approved June 14, 1889, to establish a State Naval Militia of three battalions of Naval Reserve Artillery, and a Naval Reserve Torpedo Corps to consist of not less than four companies to a battalion.

In 1890 little was done except in the way of perfecting the organizations in States which had passed laws. The Massachusetts Naval Battalion drilled on board the receiving ship Wabash and the New York Battalion on board the receiving ship Minnesota. The year 1891 was, however, a most important one. On March 2, 1891, Congress appropriated $25,000 for arms and equipments for the Naval Militia, and in June the Department issued regulations governing the disbursement of the fund pro rata, one allotment being paid on July 1st and a reserve allotted on October 1st. On March 31, 1891, an act was approved in California for a naval battalion. The Governor of North Carolina granted permission (September 23d) for the formation of a battalion of naval artillery, to consist of not less than two batteries, as a part of the National Guard. No law was passed directly authorizing the establishment of a naval militia. In the same way the Galveston Artillery Company was ordered by the Governor of Texas enrolled as a "battery for sea-coast defense," and was recognized by the Department as a naval militia force in Texas.

On October 1st, 1891, the total militia strength was (officers and men) as follows:

California	371
New York	342
Massachusetts	238
North Carolina	101
Rhode Island	54
Texas	43
Total	1149

On August 25, 1891, the oyster police force of Maryland reorganized as a Naval Reserve Battalion of three companies, but it was not recognized by the Department till the next year. Pennsylvania organized as a civic organization in September, 1891, but was not mustered in till the following year.

During July, 1891, the naval battalions of Massachusetts and New York, with the Rhode Island naval militia distributed amongst them as volunteers, were drilled on board the vessels of the Squadron of Evolution under the command of Rear Admiral J. G. Walker, U. S. Navy.

The acts of Congress annually appropriating $25,000 for "arms and equipment" for the Naval Militia leave the disbursement of this sum "under such regulations as the Secretary of the Navy may prescribe." The regulations issued by the Department, August 23, 1892, contained a proviso to the effect that $20,000 should be allotted on October 1st and the remaining $5000 on December 1, 1892, "to be apportioned among those States whose Naval Militia (or a detachment thereof) have actually drilled on board a vessel-of-war for a period of not less than four consecutive days at some time between June 1st and December 1, 1892, to be distributed in the proportion which the detachment so drilled from each State bears to the whole number so drilled from all the States," etc.

During 1892 the legislatures of Maryland, Vermont and South Carolina passed acts relating to the Naval Militia, approved respectively April 7th, November 21st and December 15th. The Lafayette Artillery of Charleston, S. C., and the Beaufort Volunteer

Artillery of the same State transferred to the Naval Militia, and the Galveston Artillery dropped out. On May 18th the Pennsylvania organization made application to the Governor of that State to be enrolled, but owing to the troubles at Homestead, Pa., this was not done till October 29th, too late to share in the annual appropriation for that year.

The returns of officers and men for October, 1892, were as follows:

Rhode Island	58
Maryland	124
South Carolina	208
North Carolina	296
Massachusetts	331
California	376
New York	401
Total	1794

During the summer of 1892 the Naval Militia organizations were drilled as follows:

Forty officers and men of the North Carolina Naval Militia paid their own expenses to Norfolk, Va., there being no appropriation by the State, and were quartered on the Franklin from June 13th to 18th and drilled on board the Newark. The Massachusetts Naval Militia were drilled on board of the Wabash, Chicago and Atlanta from July 5th to 9th, and the New York divisions on board the New Hampshire, Chicago and Atlanta, July 11th to 23d. The California Naval Militia drilled at various times in August and early in October on board the Charleston.

In 1893 the following States passed laws relating to the Naval Militia, which were approved on the dates named: North Carolina, March 6; Michigan, May 31; Illinois, June 21; Connecticut, July 1; and Georgia, December 19. In the regulations of the Department governing the distribution of the annual appropriation for 1893, "only uniformed petty officers and enlisted men" were hereafter to be considered in making the apportionment, one-half of the allotment due any State to be withheld until the Governor shall inform the Department officially "that a proper naval uniform has been adopted and issued to its Naval Militia." Notice was also given that all arms and equipment issued by the

Department should remain the property of the United States, and should be receipted for and annually accounted for on blank forms furnished by the Department.

By a joint resolution of Congress, approved November 3, 1893, the model battle-ship Illinois at the World's Columbian Exposition at Chicago was transferred to the State of Illinois as a naval armory for the use of the Naval Militia of that State.

The annual return of the strength of the Naval Militia (petty officers and enlisted men) in the various States for 1893 was as follows:

Massachusetts	589
Rhode Island	119
New York	410
Pennsylvania	150
Maryland	130
North Carolina	262
South Carolina	204
California	301
Illinois	211
Total	2376

During the summer of 1893 the following facilities were afforded the Naval Militia for drill and instruction on naval vessels: The Naval Militia of Massachusetts were embarked on the San Francisco and Miantonomoh from July 18th to 21st, a sufficient number of their regular crews having been temporarily transferred to the Wabash to make room for them. The Bristol Division of the Rhode Island Naval Militia were embarked on board the Miantonomoh for four days' drill. A part of the Philadelphia divisions of the Pennsylvania Naval Militia and the two separate Rochester divisions of the New York Naval Militia received four days' instruction at sea on the flagship San Francisco, a sufficient number of the regular crew of the ship being transferred to the Vermont to make room for them. The 1st battalion of the New York Naval Militia spent a week on board of the old line-of-battle ship New Hampshire at anchor in Cold Spring Harbor, Long Island. The North Carolina Naval Militia received four days' instruction in drill and target practice on the Kearsarge. After their tour of duty the monitor Nantucket was turned over to the Governor of North Carolina for the use of the Naval Militia of that State. Owing to a disastrous storm on the coast the Naval Militia of South Carolina did not go to sea on the Kearsarge as intended, and owing to the fact that no man-of-war was available on the Pacific Coast the Naval Militia of California did not get a cruise.

In 1894 New Jersey and Virginia passed laws authorizing the formation of Naval Militia battalions, and Michigan and Connecticut organized divisions at Detroit and New Haven respectively. A bill was introduced in Congress authorizing the formation of a battalion in the District of Columbia, but it did not become a law. An act was passed by Congress and approved August 3, 1894, authorizing and empowering the Secretary of the Navy to loan temporarily to any State vessels of the Navy "not suitable or required for general service, together with such of her apparel, charts, books and instruments of navigation as he may deem proper, said vessel to be used only by the regularly organized Naval Militia of the State for the purposes of drill and instruction."

The annual return of petty officers and enlisted men in the Naval Militia organizations of the various States for 1894 was as follows:

Massachusetts	448
North Carolina	168
Rhode Island	113
South Carolina	208
Connecticut	65
California	320
New York	432
Illinois	367
Pennsylvania	217
Michigan	73
Maryland	128
Total	2539

During the summer of 1894 the Naval Militia organizations received instruction on board naval vessels as follows: Massachusetts encamped her brigade on Lovell's Island, Boston Harbor. During the encampment the monitor Passaic was loaned to this

State, and drills and target practice were had on board the Miantonomoh and Atlanta. The two divisions of Rhode Island drilled on board the Miantonomoh. Connecticut's force received instruction on the Atlanta in Long Island Sound. New York's battalion and the two separate divisions from Rochester spent a week on board the New York and San Francisco in Gardiner's Bay, Long Island. The Pennsylvania contingent from Philadelphia and Pittsburg were embarked on the New York and incidentally had target practice at sea. The Montgomery co-operated with the Nantucket at Smithport, N. C., in instructing the battalion of North Carolina. Maryland and South Carolina did not avail themselves of an offer to embark for instruction. No ship was available for the forces of California, Illinois or Michigan.

SUGGESTIONS AS TO ORGANIZATION.

In most of the States the naval militia laws and regulations are practically those of the general military code of the State with a few additional sections or chapters devoted to their peculiar needs. For this reason it is impossible to more than suggest a few leading features which will tend to make the organizations more uniform.

Provision should be made for the performance of the annual tour of duty outside of the limits of the State whenever in the judgment of the commander-in-chief of the State forces it shall be expedient to do so, especially where a scheme of joint instruction shall be proposed by the Navy Department at some important strategic point in an adjacent State.

The rank and designation of commissioned and petty officers of the naval militia should be the same as the corresponding ranks in the navy. The commissioned officers should be designated in the law, but the number and rank of petty officers should be such as the commander-in-chief of the State forces may from time to time prescribe. This will enable changes to be made to correspond with any new or changed ratings in the navy without the necessity for appealing to the legislature from time to time to amend the law.

The pay should be the same as that of commissioned officers, petty officers, and seamen of the navy of corresponding grades or classes. Where four days of the annual tour of duty shall be spent in boat reconnoissance work or cruising, or where one or more vessels of the navy shall co-operate with the organization during said period for purposes of instruction, the duty shall count as "sea duty," and the pay shall be "sea pay" for the tour. Where the organization is called out by the State for local purposes in time of riot or domestic violence, or for other causes, the duty shall be regarded as "shore or other duty," unless performed afloat, and the pay shall be "shore pay."

What are known as "companies" in infantry or "batteries" in artillery should, in the naval militia organizations, be designated as divisions. From two to four divisions should constitute a battalion, and from two to four battalions a brigade, designated as a naval brigade. The naval battalions should be treated as battalions, and not as part of a regiment of the national guard or land militia of the State. The maximum number of petty officers and men in a division should be one hundred. The minimum may vary in each State according to discretion, but a certain group unit should be recognized. Sixteen men and one petty officer is the minimum subdivision or group unit. This is a boat's crew, a section of artillery (field), a torpedo crew, or an engineer's section. It will also be a unit or multiple in the new infantry tactics. To each division there may therefore be attached groups of the artificer or special classes as additional to the small divisions in some of the States. The number and ratings of the petty officers should be regulated, as before stated, from State headquarters.

The officers of the naval brigade should consist of a captain as chief of brigade, and a staff consisting of one commander as chief of staff and executive officer; one lieutenant as brigade adjutant and chief navigating officer; one lieutenant as chief signal, ordnance and equipment officer; one paymaster, one surgeon, and one chief engineer of the relative rank of lieutenant; one ensign as signal officer, and one ensign as aide to chief of brigade. These officers should be chosen and commissioned as soon as two battalions are completely organized.

Where the maximum organization allowed in a State by law is a battalion, the commanding officer should be a commander and the executive officer a lieutenant-commander. To each battalion in a brigade organization, however, there should be one lieutenant-commander to command the same; and a staff officer to consist of one lieutenant as battalion adjutant and executive officer, one lieutenant as navigating, ordnance and equipment officer, one ensign as signal officer and assistant to navigating, ordnance and equipment officer; one surgeon and one paymaster of the relative rank of lieutenant (junior grade), and one assistant surgeon of the relative rank of ensign. To each division there should be one lieutenant to command the same, one lieutenant (junior grade), and one ensign. Each separate part of a battalion not in the same county of the State as the battalion headquarters should have one assistant surgeon of the relative rank of ensign, and one additional ensign for each division.

A very good regulation obtains in Connecticut by which seamen are divided into three classes, 1st, 2d, and 3d, although the pay is the same. The power to rate or disrate should be lodged with the commanding officer, to thus give him power to discipline or reward men, and to discriminate between recruits and those who have served some time and are efficient.

The necessary outfit to completely equip a brigade, battalion, or division of the naval militia is outlined in the annual report for this year.

The uniform of both officers and men should be of a naval pattern, but the State coat-of-arms should be worn in conjunction with rank devices.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

By Charles E. Munroe.

No. XXVI.

Through the courtesy of Col. Majendie we are in receipt of the *18th Ann. Report of H. M. Insp. Exp., 1893,* which, like their former reports, is replete with interesting and valuable information. It is impossible, with so voluminous a report, to do more than briefly allude to but a few of the interesting facts presented, and we note, first, that the importations of dynamite for 1893 are 90 per cent., of gelatine dynamite 9 per cent., and of matagnite gelatine 68 per cent. less than for 1892, while that of detonators is increased, over 7,179,000 having been brought in. In the required tests of explosives imported and sold, all the dynamite samples were very satisfactory, but of the plastic explosives the same cannot be said, as 33 per cent. of the blasting gelatine and 23 per cent. of the gelignite samples failed.

The danger from accidents with frozen plastic explosives, especially while thawing them, is dwelt upon at length, the admirable instructions of the Nobel's Explosive Company on this matter being given in detail, and it is stated by the latter that blasting gelatine may become congealed at temperatures as high as 45° F. without altering the soft and plastic outward appearance of the cartridges. In his report, Dr. Dupré says that while only three out of 78 samples of gelatinized preparations failed to pass the heat test, a far larger number came very near the limit,

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*As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. *Address, Columbian University, Washington, D. C.*

and he again urges that both the nitroglycerin and nitro-cotton used in these preparations be purified to such a degree as to stand the heat test for a longer time than that required officially for each by itself. Mr. Hake, inspector of explosives in Australia, calls attention to the fact that certain grades of gelatine dynamite containing wood meal suffer considerably, as regards stability, during their passage from England, and the spontaneous explosion of over 17,000 pounds of blasting gelatine at Matoonga, Bombay, December 28, 1891, shows that their continued stability is not yet assured. Taking the facts of this accident with that at Aden in 1888, and probably certain others in India, it would appear that the destructive change in the explosive in such a climate is effected in three to four years.

Among the many accidents recorded is a very detailed and non-sensational account of the frightful explosion at Santander, Spain, November 3, 1893, from which it appears that about 33 tons of dynamite were exploded, 510 persons were killed and about 2000 wounded. A singular case was that of the explosion of about one ounce of nitroglycerin in the converter at Perranpath, Cornwall, September 5, 1893, due, it is believed, to the acids and nitroglycerin retained by the scale and rust accumulated in the bottom of the converter. The explosion of ecrasite in the laboratory of the Austrian War Office, August 1, 1893, while a projectile was being filled with it, is of especial interest to ordnance officers, though unfortunately no details are given. The accident at Waltham Abbey, March 2, 1893, was a remarkable one, since 4212 pounds of gun-cotton in the drying stove caught fire and burnt up without exploding, though 308 pounds at Ardeer, on October 27, 1882, under somewhat similar circumstances, produced a violent explosion.

The fire at Tangye's safety-fuze factory, August 10, 1893, furnished some interesting results, in that 144,000 feet (nearly 28 (?) miles) of "tube safety-fuze," containing one and one-half ounces of gunpowder to every twenty-four feet, were consumed without any explosion whatever.

The new explosives examined were westfalite, a mixture of ammonium nitrate and gum lac, Von Förster's powder, a pure nitro-cellulose thoroughly gelatinized and mixed with a little chalk, and Schnebelite, a powder containing a small percentage of potassium chlorate.

Through the courtesy of Dr. T. M. Chatard we are in receipt of a copy of his address as president of the Chemical Society of Washington, entitled "The Abuse of Explosives, with Suggestions for Preventive Laws."*

After describing the properties and methods of manufacture of the characteristic explosive substances, Dr. Chatard says:

All explosives, in their nature and mode of production, can be divided into a few classes; the processes of manufacture are in principle very simple; and all sorts of mixtures can be made which are easily exploded. Under such conditions it is evident that prevention of their vicious use is surrounded with peculiar difficulties in addition to those which are always met with in attempting to control the sale or use of articles for which there is a legitimate general demand.

Granting the necessity of legislation to prevent abuse of explosives, we may lay down the general principle that it cannot be made effective if it interferes unduly with legitimate manufacture and employment.

In all engineering work, high explosives, when used, are not luxuries, but necessities. Not only can work be done more cheaply by their aid, but often could not be done without them. Examples might be given, but it is perfectly well known that this necessity is absolute, and that the great development of the explosive business has been caused by the demand of the engineer. He requires that his explosives shall be safe to transport, store, and handle, certain and powerful in action, and that the combustion shall be complete, leaving no deleterious residues. To satisfy these requirements the manufacturer must employ all the resources of skill, and only well-managed works can produce reliable articles in an economical manner.

It is not believed that the abuse of explosives can be prevented by governmental inspection or supervision of manufacture, transportation, or even sale. The laws of France are most minute on these points, but do not prevent outrages. Legal regulation may and can protect the workmen, the inhabitants of a neighborhood, the transportation agents, or the traveling public. For excise purposes, supervision of sale may be necessary, but cannot prevent crime. Explosives purchased from legal dealers and strictly according to provisions of law may be unlawfully used; they may

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* Bulletin No. 8, Chem. Soc., Washington, Gibson Bros., 1893.

be stolen from lawful possessors by intending evil-doers, or the latter can easily obtain the materials for making their own explosives. Nitric acid, an essential, has such extended uses that it can be bought at any druggist's. Nor is it necessary to purchase the acid, as it can be easily made by distilling a mixture of nitrate of soda and sulphuric acid, both of which are in common use among farmers for composts and other home-made fertilizers. It is also very likely that in most cases of carefully planned outrages the explosives would, in part at least, be made by the conspirators.

But although governmental supervision of manufacture, storage, transportation, sale and use cannot be relied upon to prevent the vicious use of explosives, still this supervision would be an important aid. Moreover, such supervisional control, if acting under acceptable regulations, can be made very beneficial to this industry, and would be welcomed by most of those immediately interested. Col. Majendie, in a most interesting and valuable report on the operation of the laws affecting the manufacture and handling of gunpowder, shows that the English powder-makers, far from objecting to a rigid system of control, were glad to record themselves in favor of it, if it were made reasonable and general, and then rigorously enforced.

The reason for this is plain. Arrangements for the protection of the works, the workmen, and the neighborhood cost money, both to introduce and to maintain. If one manufacturer endeavors to protect his works or workmen by special improvements, care and regulations, he will not be able to produce as cheaply as his competitors if the latter are permitted to work without restriction. The same thing is true in the case of transportation agencies and dealers. The former often find it necessary to make regulations governing the transportation of explosives, and should always be aided by the law in enforcing them.

Such regulations when made by private individuals or corporations are always difficult to enforce. Even when clearly made for their own protection, workmen often stubbornly resist them and try to evade them in every way, nor is it easy to punish disobedience when detected. Nor is the general public much superior in this respect. The cry of tyranny is raised, and the demagogue, in his glory, vehemently denounces these encroachments on freedom.

If this supervision is desirable, the law should be national and general, passed by Congress and enforced by the General Government. State laws, however good, stop at the State line, and the best intentions of local legislators are often paralyzed by representations that their action will "drive away business," "lose votes," or any other of the cant phrases. The present condition of the oyster industry in Maryland is an instructive lesson, for there a small minority of people, who being well intentioned but ignorant of their true interests, have successfully resisted every attempt to prevent them from killing their goose, to the damage of the interests of the entire State. The law should provide a certain *minimum* of regulation—should be a minimum law.

Before attempting to frame such a law, a careful investigation and study of the practical requirements should be made by a commission appointed for the purpose. It should be made clear to all those interested—manufacturers, railroad men, dealers, engineers, miners, quarrymen and other workers—that their opinions, advice and criticism are sought for and are welcomed; that no legislation will be recommended until its provisions and their practical effect have been thoroughly discussed and substantially agreed to by them; and that no more legislation will be attempted than that which they themselves consider as the minimum amount necessary for the general welfare and protection. Intelligent newspaper discussion will be especially valuable, for it will clarify the public mind and detect deficiencies and defects which might otherwise escape notice until a time when their discovery might inflict serious injury on the whole matter.

Having thus investigated the subject, the commission can present to Congress its conclusions in the form of a general law providing for this minimum amount of control. As this law will have been already thoroughly discussed, understood and approved, the final sanction should be easily obtained. A law thus carefully framed should need but little machinery for its enforcement. Regulations suitable and acceptable to each branch of the business can, in the light of the previous investigations, be easily made under its provisions, and when officially promulgated would be binding on all. Methods of procedure against offenders should be simple, direct and summary.

Any serious attempt to prevent the vicious use of explosives will, however, compel us to go further, but in the same direction.

We must have a national and general license law, under which the *simple, unlicensed possession* of any explosive, except those especially excluded, shall be punishable. The excluded explosives should be fireworks and ordinary gunpowder, either loose or in cartridges. Fireworks are sufficiently well looked after by local authority, and any attempt to interfere, in this manner, with the use of gunpowder will result in failure. We must not attempt the impossible; what is possible will be hard enough to attain. The wording of the licenses will have to be varied to suit the circumstances; but, in fact, but few forms will be necessary. They should be obtainable at the least possible cost, with the least possible inconvenience; and the granting of them should not be discretionary, but be under rules clearly laid down. Discretionary action in this connection is wholly unnecessary and would be injurious.

How such a law would work in practice will best be shown by considering some particular cases. A chemist desires to carry on an investigation in explosives. He personally presents his written application, giving whatever information the general regulations may require, and receives his license. This entitles him and his assistants under his direction to do whatever work he may desire within the limits of his laboratory, but does not permit him or any one else to carry his explosives outside of those limits, or even to take them to some other place for further experimentation. For this purpose another form of license, equally easily obtainable, should be required. These restrictions interfere in no way with his scientific or practical work, but do aid in protecting the public.

Now let us consider the mining industry. If the license system will work well in that branch of engineering, it ought to in any other. A new mine is to be opened, and somebody is put in charge of the work. When it becomes necessary for him to procure explosives he goes to the nearest licensing office, files an application, which, again, is made out according to a prescribed form, and on payment of a very small fee receives an appropriate license. This license confers upon the licensee the right to store and use explosives upon the mining property, the name, location and limits of which are sufficiently nearly described in the license. Outside of those limits the license is entirely void. Included, but in express terms, is the permission to purchase explosives of any kind or in any quantity, whenever and wherever the licensee may desire, and to convey the same to the property, either from the dealers direct or from the most conveniently situated public transportation point. The license should be personal and non-transferable, should run for not more than one year from date, and then *absolutely* expire. Renewal, if desired, should be an entirely new transaction, which can occur during the life of the first license, which must, of course, be simultaneously surrendered and destroyed. There would be no increase of restrictions on the purchase of explosives in consequence of this license law. The dealer should not be required to know that the purchaser is licensed. If any sale restrictions are introduced, these should come through the operation of the general code of dealers' regulations, framed for their protection, as previously indicated.

In the same way the transportation agents need only require that the packages of explosives are properly prepared for shipment, according to their own special code. Their responsibility would be the same as at present and would cease with the delivery of the goods. As to the conveyance of the explosives from the dealer's store or the railway station to the mine, this should be covered by the license. Some regulation for wagon transportation may be necessary, but otherwise no special liability should attach to the teamster during *bona fide* transit.

The explosives having reached the mine, are issued to the miners for use. This use is covered by the license to the superintendent, who may, as at present, make whatever rules for its conduct he may deem advisable. Certain regulations, however, should be made obligatory by law. In some cases the miners are furnished with explosives at the expense of the mine; in others they buy them from the management as they do their oil, candles, etc. If, at the end of his shift, a miner has any surplus explosive, he must deposit this in an appropriate place, provided by the company, where he can get it at the beginning of his next shift. Whether he has purchased it or not should make no variation in this regulation. Under no circumstances should he be permitted to take explosives to his dwelling-place, even if this be within the limits of the mining property. His family and neighbors must be protected. As to carrying it outside of those limits, both superintendent and miners stand on an equal footing. Both are absolutely forbidden to do so. If work is to be done on a neighboring property, another license must be obtained for this. If the general magazine is situated on the first property, the new license can permit conveyance from one place to the other.

There is no occasion for licensing the individual miners, nor should this ever be done. There should be but one license for any one place, and that should be issued to the superintendent alone. Only through his permission can any one, within the limits of the property, legally have possession of any explosive.

With some changes in language the mining license will serve for the needs of the farmer, who sometimes finds it advantageous to use high explosives for the removal of stumps and rocks, and for other purposes—within the limits of his farm he may use them; outside of it, not at all. A special form of license covering a certain district, say a county license, will be necessary for well-diggers and others whose work is in the form of jobs of indefinite duration and location. The same may be said of prospectors, whose mode of life and manner of work present peculiar difficulties in the way of control.

Having in this manner provided for the needs of all legitimate business, we can then insist that the unlicensed possession of explosives shall be punishable, without reference to the intentions of the transgressor. The law of the District of Columbia concerning concealed weapons is an example. A man may be arrested for some trifling offense, but it is found that he has upon his person a concealed weapon. He makes no attempt to use it, but he has it. When he is brought up for trial he may even be acquitted of the offense, but is fined $50 or punished by an equivalent imprisonment for having the weapon. His intentions are not considered; the fact is sufficient for condemnation, and there is no appeal. Of course the previous arrest has nothing to do with this, except as having given the opportunity to ascertain the fact.

Some such summary proceeding will be necessary under the license law if this is to be effective. Inasmuch as there will be no reason for unlicensed possession, the proof of fact will be sufficient. As the licenses are local and limited, the chances of detection of illicit actions will be greatly increased, as the real licensees and the nature of their licenses will be generally known. Moreover, any licensee transgressing the limitations of his license becomes at once amenable to a punishment, which some of his neighbors at least will see to it that he gets. In offenses against this law, evil intentions should be presumed. If their absence can be satisfactorily proven, then the punishment can be reduced to a minimum; but there should always be a punishment, which for many reasons should be an imprisonment, with or without a fine, but need not be heavy or severe.

Dynamite outrages are generally planned and the explosives procured some time in advance. The power of summary arrest for possession conferred by this law would much increase the chances of prevention, for it would only be necessary for some secret information as to this possession to reach the proper authorities to enable them instantly to arrest the offending parties. The finding of the explosive would be quite sufficient for condemnation without the necessity of exposing the informer. During the resulting imprisonment further investigation could be made, but one such arrest would probably prevent the execution of the plan by the others concerned. Again, if the penalty for simple possession be not made too severe, the probability of obtaining such secret information will be much greater. As the laws are at present, should any one of a group of conspirators be seized with remorse and desire to prevent an intended outrage, he can only do so effectively by betraying the criminal intentions of his fellows. He knows that if he does this he will probably be compelled to give public testimony upon which may depend the lives of others who have trusted him and who are probably no more guilty than he. Moreover, through this publicity not only must he undergo all the obloquy which society, while availing itself of his services, heaps upon the informer, but also expose himself to private vengeance. This he may well hesitate to do; but if such a man knew that by merely revealing the fact of possession the outrage could be prevented without exposing any one of his fellows to any greater punishment than that attaching to illegal possession, it is reasonable to suppose that useful pre-repentance would be more frequent. It is prevention, not punishment, that is to be sought for.

The power of summary action and arrest for possession is indispensable. The authorities should be empowered to act at once upon information, and no other warrant for search or arrest should be required. Secrecy and suddenness of action will have a far more paralyzing effect upon the dynamiter than any display of the majesty of the law, which it is his purpose and study to defy and make contemptible. To those who may object that such proceedings would be too high-handed, unconstitutional, etc., it may be replied that it is time that some of the technicalities that have been carefully built up around our laws should be swept away and justice be less impeded. It is time that some change should be made in the principle that law-abiding people must wait until the vicious perform overt acts before any legal steps can be taken to restrain them, and that then these steps, to be legal, must be according to rules apparently framed to give the greatest amount of trouble and expense to the prosecutor and the greatest chance of escape to the offender.

We do not need very severe laws to check dynamite outrages. A law which is plain, just and simple—under which detection will be easy and punishment certain—will require no heavy penalties to make it effective, so far as mere unlawful possession is concerned, but any attempts to make a criminal use of explosives—any threats, verbal or written, to do so—any incitements, verbal or written, of others to make such use against anybody in particular or society in general, or an expressed approval of such actions, should meet with speedy and severe punishment, which no legal technicalities should be permitted to delay. Such things are done and said to disturb and terrify the public, and usually by persons to whom the certainty of close confinement at hard labor will act as an effective deterrent. The Johann Mosts, O'Donovan Rossas and Louise Michels of society would speedily find their occupations and themselves gone to the penitentiary, where their usefulness to the world would be much increased. Of course those who are entrusted with the execution of such a law must be especially watchful lest its purpose be perverted to a means for private revenge or persecution. These may occur in any branch of criminal law, but must always be suspected and looked for in this connection, since secret information must be so much depended upon. If their existence is proved, the offenders should be most heavily punished, and none of the technicalities impeding convictions for perjury in ordinary cases should be permitted to have any force here.

It has been said that the licenses should specify the use. This should be broadly considered. What is meant is that such misuses as killing fish with dynamite, explosions for amusement, etc., shall be absolutely prohibited, license or no license. They are either barbarous or wholly unnecessary.

The excluded explosives are fireworks and gunpowder. All desirable amusement and noise can be obtained by their use. It is true that quite as disastrous outrages can be perpetrated by the aid of gunpowder as by that of dynamite, but its employment has not such a terrifying effect upon the public, who are accustomed to its use, which they could not be deprived of even if this were desirable. The recent introduction of smokeless powders for sporting purposes brings in, however, new complications. These powders are from two to four times as powerful as ordinary gunpowder, and are quite as effective for outrages as any of the dynamite preparations. How far their use should be controlled would be a matter for special consideration, but a license ought to be required for their possession. Convenient as they are, they are not necessary either for sport or protection. The great hunters, such as Gordon-Cumming, had not even breech-loaders; the old flint-lock served our purpose at Bunker Hill and Bennington, and was more than we wanted at Bladensburg; while if any son of the Revolution, American or otherwise, will load up his ancestor's horse-pistols and shoot as straight as we hope the old man did, his burglar will be as completely *hors de combat* as if he had been operated on by the latest improvement in firearms.

In 1894 Senator Hawley introduced into the Sundry Civil Bill H. R. 5575, 53d Congress, second session, the following clause: "To enable the Secretary of the Treasury to investigate and report upon the importation, use, transportation and manufacture of high and low explosives, with the view of securing by legislation greater security to life and property, five thousand dollars."

Acting on this, the Secretary of the Treasury appointed Mr. West Steever, a lawyer of the District of Columbia, who, on January 1, 1895, rendered a preliminary report which appears as Ex. Doc. No. 181, 53d Congress, third session. Mr. Steever says:

"This preliminary report will be confined to the first of the four branches in which the proposed investigation was prescribed by Congress to be conducted, viz. the importation of high and low explosives from foreign countries into the United States. Owing to the fact that until of recent date the importation of explosives from foreign countries into the United States has been of an insignificant character, very little attention has been paid by Congress to regulate or restrict their introduction into this country.

"The only legislation on the statute book relating to the subject of the importation of high explosives from foreign countries into the United States is the act of Congress approved July 3, 1866 (Stat. at L., Vol. xiv, p. 81), and forming sections 5353, 5354 and 5355, under the title of Crimes, and sections 4278, 4279 and 4280, under the title of Commerce and Navigation, of the Revised Statutes of the United States.

"Section 5353 is a 'qui tam' action, and prescribes, among other provisions, for the importation in passenger conveyances of certain high explosives which have long since been discarded for more modern discoveries and consequently may be considered absolutely as a dead letter. No conviction has ever been reported in the books under this section, and an indictment under it for the importation of the recently discovered explosives would certainly be quashed by any court before which it would be brought.

"Section 5354 makes the offense, in addition to the 'qui tam' feature as above, manslaughter, with term of imprisonment for a period of not less than two years. This law, for the same reason, would even be still more difficult to enforce, for the obvious objection that it would involve a criminal conviction for the importation of high explosives totally unknown when the act of Congress was passed, and which are the only explosives now known to commerce.

"Section 5355 prescribed a 'qui tam' action if these long since discarded explosives are not packed in metallic vessels surrounded by plaster of paris and marked 'Nitroglycerin, dangerous.'

"It is hardly worth while discussing this section, as the described explosives no longer form a part of commerce, and modern science has found that there is no more dangerous mode of packing any high explosive than placing the same in metallic vessels, as prescribed in this section. As Berthelot declares that no explosive more powerful has yet been discovered than nitroglycerin (not combined with any other substance), and as it freezes at 12° (say 54° F.), it can easily be conceived how dangerous it would be to transport this explosive in the mode prescribed in this section. The exuding of nitroglycerin was supposed to be the only cause of its being subject to premature explosion, and the plaster of paris surrounding the receptacle was supposed to render it innocuous, but this idea has long since been discarded. The great danger is undoubtedly by its liability to freeze, and in this state it will explode even without any perceptible cause to the human sense.

"Sections 4278 and 4279 declare that it shall not be lawful to transport the said explosives between any foreign country to a place in any State, Territory, or District of the United States, and between any place in one State, Territory, or District of the United States and a place in any other State, Territory, or District of the United States, or any passenger-vehicle, or any vessel or vehicle of any description upon land or water, except packed in a metallic vessel surrounded by plaster of paris, and marked 'Nitroglycerin, dangerous.' These sections are obsolete for the reasons already adduced, as explained in commenting on the criminal and 'qui tam' sections above.

"At the time of the passage of the above-mentioned act of Congress very little was known definitely in regard to the composition or action of high explosives. It is true that Nobel had discovered dynamite a few months previous, but the manufacture has not been so perfected as to make it an article of commerce, and I am satisfied that no court would entertain for a moment such a strain of the language used as would bring any of the modern explosives within the purview of the penal sanctions of the statute.

"It is now nearly thirty years since Nobel made this great discovery, which proved to be the first practical step in the development of the manufacture of high explosives. During that period changes amounting almost to a revolution in the art of war have occurred by its use, and its influence in the peaceful avocations of life has not been of less importance. We are, though, but on the threshold, and there is every probability of even still greater changes in the near future. The great problem heretofore existing is to find some means to control the pressure generated by a high explosive, while eliminating what is technically called its 'work.' It is claimed that this has been recently accomplished in England, and an engine in the form of a ram for pile driving has been constructed, in which explosive power is used instead of steam, and, though still crude in principle, the work for which it is used is done with surprising energy and is far superior to the relative steam engine used for the same purpose.

"Section 4280 is a proviso that none of the preceding sections shall be so construed as to prevent any State, Territory, District, city, or town within the United States from regulating or prohibiting the traffic or transportation of those substances within their said limits, or from prohibiting their introduction within said territorial limits for sale, use, or consumption therein.

"In the case of Bowman *v.* Chicago and Northwestern Railway Company, these sections of the Revised Statutes were discussed by the Supreme Court of the United States. Mr. Justice Matthews delivered the opinion of the court in the following language (125 U. S., 484):

> But sections 4278 and 4279 relate also to the transportation of nitroglycerin and other similar explosive substances by land or water, and either as a matter of commerce with foreign countries or among the several States. Section 4280 provides that the two preceding sections shall not be so construed as to prevent any 'State, Territory, district, city, or town within the United States from regulating or from prohibiting the traffic in or transportation of those substances between persons or places lying or being within their territorial limits, or from prohibiting the introduction thereof into such limits for sale, use, or consumption therein.' So far as these regulations made by Congress extend they are certainly indications of its intention that the transportation of commodities between the States shall be free, except where it is positively restricted by Congress itself or by the States in particular cases by the express permission of Congress.

"I would beg, also, to state that in my investigation of the laws of the different civilized nations in regard to regulating the importation of explosives, all such laws are framed so as not to interfere with the local laws and ordinances in force at the time of the promulgation of the general law. It stands to reason that no general law can regulate the subject without taking into consideration such local laws and ordinances suitable to the different localities for which they are enacted. As much activity in effecting general legislation on this subject has been displayed in the past twenty years in Europe, I beg to submit an epitome of the laws of the leading nations which have more particularly regulated the importation of explosives within their limits, and which is hereunto appended and marked A.

"I regard the enactment of a law regulating the importation from foreign countries into the United States of both high and low explosives as the first step toward 'securing by legislation greater security to life and property.' Perhaps no commerce between nations is so fluctuating as that of explosives. Statistics show that one year may differ entirely from another, both in quantity and kind, and this is governed by the variety of demand and supply created by new discoveries and inventions, subject to all the contingencies of human life in peace and war and which cannot possibly be foreseen by the home manufacturer. The past year is a fair index, as in the early part the importation into this country was confined almost entirely to the ingredient nitrates and glycerin, but latterly a large amount of high explosives have arrived on our shores.

"Taking these views into consideration, I would beg to submit, to be embodied into legislation in part or the whole, a bill 'to regulate the importation of gunpowder, nitroglycerin and other explosive substances,' which is herewith attached and marked Appendix B.

"The classifications in this bill have been made as closely as possible to those prevailing in Europe, due regard being paid to the recent discoveries and inventions. The picrate division is, perhaps, the greatest departure, and that has been caused by recent developments in the manufacture of that kind of explosive in France and other countries. The mode of packing is that which is insisted upon in Great Britain, and which has been adopted more or less, or recommended to be adopted, all over the Continent. As the classifications include only the foreign explosives, the packing of such does not affect that prevailing in the United States or imported packages after breaking bulk. I have purposely abstained from introducing in this bill the 'qui tam' features which prevail in our legislation, as no other civilized nation has adopted such in its regulations of the importation of explosives so far as I can discover after diligent search. While the bill creates no new offices, ample means are provided for elasticity in its enforcement in giving discretionary power to the Secretary of the Treasury to grant permits waiving compliance with the stricter regulations contained therein in case of war or like necessity.

"I am satisfied that if the provision of the proposed bill herewith recommended had been a law, or some other legislation of like character had been in existence at the time, that the dynamite fiend, Alexander Keith (alias William King Thomas, alias William King Thomson, alias George S. Thomas, alias Garne) could never have perpetrated the diabolical crimes with which he has been credited. By shipping explosives from European ports to New York, and then having the same sent back for re-exportation on steamers on which he over-insured goods, he was enabled to hoodwink the police authorities of the eventual ports of departure, and it was only by an appalling accident at Bremerhaven, on the 11th of December, 1875, that his plan of wholesale murder was unearthed. A chest, which had previously made the voyage to New York and returned, and conjectured to contain about 1000 pounds of lithofracteur, while being shipped on board the Mosel is supposed to have slipped out of the hands of the carriers and then falling to the ground exploded with terrible effect. Over one hundred persons were killed and many others more or less injured. A hole 30 feet in circumference and 8 feet in depth was made in the solid stone pavement and soil beneath the quay, and parts of the decks of the Mosel and Simoon tugboat, lying alongside, were carried up in the air and thrown to considerable distances. Everything which presented any resistance was destroyed within 2500 feet. Considerable light damage was done within 10 miles, and the report of the explosion was distinctly heard at a distance of 55 miles from Bremerhaven.

"The author of all this destruction of life and property committed suicide, but confessed before his death that the case was furnished with a clockwork apparatus which was intended to be wound up at Southampton (England) and which, after eight days, would operate to cause the explosion. A quicker trip than usual at this time of the year or a breakdown, causing delay in the clockwork apparatus, might have transferred the scene of explosion to New York harbor instead of Bremerhaven, with still greater destruction of life and property. It is supposed that several steamers that never were heard from were sent to the bottom by this fiend in human shape and by means of like contrivance. It was discovered that his business connections were with leading bankers and manufacturers, and but for the Bremerhaven accident he might have continued his career of crime for an indefinite period of time. After the revelation made through the confession of this ingenious enemy of the human race, it was high time for the civilized nations of the world to take measures to protect life and property from the machinations of such depraved scoundrels. In this international legislation the United States has lagged behind, I am convinced, not from want of sympathy in the objects to be effected by such legislation, but, owing to our system of dual government, rather from a morbid feeling of dislike to appear to interfere within the sphere of the jurisdiction of the sovereignty of the different States composing the Federal Union.

"I would beg also to call your attention to a still more recent catastrophe caused in great part by lack of needful legislation." The writer here describes the Santander explosion, an account of which is given earlier in these notes from the report of H. M. Inspector of Explosives. He then remarks regarding the accident:

"A glance over the provisions of the legislation as recommended herein will show that an accident inflicting such extensive damage would be impossible to occur at any port of the United States, owing to the restriction of 50,000 pounds to a single cargo imported, as prescribed by the proposed enactment.

"I could add to the above other accidents, almost countless in number, which have occurred from the want of regulations in regard to the importation of explosives and which have forced the civilized nations of the earth into the line of legislation recommended herein, but such relation would be of superfluous weight in argument, as no opposition is anticipated from any quarter. The cost of ocean freight has steadily declined since the regulations as to packing explosives have been understood and enforced by the leading commercial nations of Europe. Before these regulations and restrictions became law, few vessels would accept any cases of explosives as part of their cargo, and, consequently, the rates of freight on such articles were absurdly high, but such regulations and restrictions being enforced by fines and imprisonment, gave confidence to the carrier, and the supply of tonnage soon was equal to the demand. Great difficulty also was found with the insurance companies, which refused to take risks either on the vessels or their cargoes where explosives were carried. Now, though no difficulty is found in placing risks, the rates of ocean insurance are as moderate as on any other merchandise.

"There are a number of railroad companies in the United States that refuse to transport high explosives under any circumstances, but upon what grounds they could justify the exclusion of such high explosives from being imported under the regulations of the legislation proposed it would be difficult to imagine. European railway companies have found it to their interest not to pursue so shortsighted a policy, as in case of exclusion the articles are carried surreptitiously concealed with other merchandise, thereby making the danger of premature explosion all the greater. Metal cylinders made to represent oil cans, the cylinders being so constructed with an inner longitudinal partition that a portion amounting to one-tenth of each cylinder was able to and actually did contain oil, while the remaining nine-tenths of the cylinder contained an explosive, was one ingenious method among many others practiced for deceit in transportation. Another almost equally as ingenious was to disguise the high explosive 'tonite' as wine and have it transported as such. In a number of instances parties have been apprehended carrying high explosives on passenger cars in carpetbags or valises and in trunks or chests checked to their destination in baggage cars. In every case the excuse for such wanton recklessness was the prohibition of the railroad company to allow the transportation of such high explosives as freight.

"It was recently asserted as an argument urged for the purpose of obtaining a reduction in the rates of freight asked on explosives, that since the regulations and restrictions by law went into effect in 1875 not a life has been lost by a premature explosion on the railways of Great Britain and Ireland, and the sum of twenty-five dollars (£5) would cover all the damage done to property on such railways up to date. It has been asserted by the railroad companies that they are not responsible for damages in cases of premature explosion if they prohibit the transportation of the explosive, but that they would be liable if transported under regulations of apparent safety but prematurely exploded. After a careful search through the authorities I can find no decision to bear out such an interpretation of the law as existing in this country. This perverted view of the law of damages was used recently in argument in a decision reached by the board of directors by one of our great systems of railroads. Although the officers were all convinced of the safety of the explosive and were willing to transport it, the board of directors decided by an overwhelming vote to continue the suicidal policy of prohibiting the transportation of any and all explosives over their lines.

"As no less than seven kinds of explosives, including detonators, are used in some mines, each being found specially adapted for different work, it can be easily perceived how such action paralyzes the development of that branch of industry in the territory, not including many others, depending for transportation on their system of railroads."

The report is accompanied by two appendixes. Appendix A contains abstracts of the legislation of Austria, France, Germany, Great Britain and Ireland, Norway and Sweden.

Appendix B is a draft of a proposed "bill to regulate the importation of gunpowder, nitroglycerin and other explosive substances," and which is as follows:

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:* That it shall be unlawful to import into the United States any gunpowder, nitroglycerin, dynamite, gun-cotton, blasting powder, fulminate of mercury, fog signals, fireworks, fuzes, rockets, percussion caps, detonators, cartridges, ammunition of all descriptions and every adaptation or preparation of an explosive to produce effect by explosion or a pyrotechnic effect, except in accordance with the regulations prescribed by this act.

"Sec. 2. For the purpose of this act explosives shall be divided into the following seven classes: Class 1, gunpowder; class 2, nitrate mixture; class 3, nitro-compound; class 4, chlorate mixture; class 5, fulminate; class 6, ammunition; and class 7, fireworks.

"Class 1 includes brown, cocoa, lightning, mammoth, olive, orange, pebble, prism, and all those gunpowders of the ordinary black kind, which are used to discharge cannons, mortars, and muskets.

"Class 2 means any preparation other than gunpowder, ordinarily so called, formed by the mechanical mixture of nitrate with any form of carbon or with any carbonaceous substance not possessed of explosive properties, whether sulphur be or be not added to such preparation, and whether such preparation be or be not mechanically mixed with any other non-explosive substance, and includes amide, cahne, carbozotine, diorexin, perulite, haloxyline, heraklin, johnite, oriental, fortis, grenadine, pudrolithe, pyrolithe, pyrononce, pyronitrine, saxifragine, triumph, safety, xanthine, and all other preparations coming within the above definition.

"Class 3 means any chemical compound possessed of explosive properties, or capable of combining with metals to form an explosive compound, which is produced by the chemical action of nitric acid (whether mixed or not with sulphuric acid), or of a nitrate mixed with sulphuric acid, upon any carbonaceous substance, whether such compound is mechanically mixed with any other substances or not. This class shall have three divisions:

"Division 1 comprises such explosives as colonia, dahmanite, diaspon, dualine, dynamite No. 1, dynamite No. 2, dynamagnite, forcite, fulminatine, gelatine dynamite, gelignite, glonoius, glukodine, glyoxiline, lignose, lithofracteur, matagnite, mataziette, meganite, nitroglycerin, nitrolite, orissite, paleine, petralithe, porifera, rendrock, rhesite, sebastine, scranine, vigorite, virite, westfalite, and any chemical compound or mechanically mixed preparation which consists either wholly or partly of nitroglycerin or some other liquid nitro-compound.

" Division 2 shall comprise such explosives as bellite, carbonite, cellulosa, di-fiamyr, emilite, glycero-pyroxiline, kinetite, nitromidine, nitasons, nitroline, nitromaanite, petrofracteur, plera, potentite, pyroxiline, roburite, romit, securite, titan, tonite, xyloglodine, xyloidine, and any nitro-compound, except picrates, not comprised in the first division.

" Division 3 will include the explosives known as bronolithe, emmonite, honitite, lithstite, melinite, oxonite, punshon, victorite, and all other chemical compounds in which picric acid is used as a nitro-substitute.

" Class 4 includes such explosives as asphaline, callow, dynamogen, etnite, inline, pyronnome, rock-a-rock, silesite, schneibelite, viel, and any chemical mixture containing a chlorate.

" Class 5 comprises all fulminates used for percussion caps or any other appliances for developing detonation.

" Class 6 includes any explosive used as ammunition when inclosed in any case or contrivance or otherwise adapted or prepared so as to form a cartridge or charge for small arms, cannon, or other weapon, or for blasting, or to form any tube for firing explosives, or to form any safety or other fuse for blasting or for shells, or to form a percussion cap, a detonator, a fog signal, a shell, a torpedo, a war rocket, or other contrivance other than a firework. This class shall have three divisions:

" Division 1 embraces safety cartridges, safety fuzes, for blasting, railroad fog signals and percussion caps.

" Division 2 comprises any ammunition which does not contain its own means of ignition, such as cartridges for small arms, which are not safety cartridges, cartridges for cannon, shells, mines, blasting or other like purposes, shells and torpedoes containing any explosives, fuzes for blasting which are not safety fuzes, fuzes for shells, tubes for firing explosives and war rockets.

" Division 3 will comprise any ammunition which contains its own means of ignition and is not included in Division 1, such as detonators, cartridges which are not safety cartridges, fuzes for blasting which are not safety fuzes, fuzes for shells, and tubes for firing explosives.

" Class 7 will include all fireworks, and is divided into two divisions:

" Division 1 comprises any firework composition containing any chemical compound which is used for the purpose of making fireworks, and is not included in the former classes of explosives.

" Division 2 includes all manufactured fireworks such as squibs, crackers, serpents, rockets (other than a war rocket), maroon, star, wheel, chinese fire, roman candle, or other article adapted for the production of pyrotechnic effects or signals.

" Sec. 3. No explosive shall be imported into the United States except by virtue of an importation license granted by the Secretary of the

Treasury, and the unloading and delivery, or the transhipping of any explosive shall be included within the provisions of this section.

"Sec. 4. The Secretary of the Treasury may grant an importation license for any such explosive, and may annex thereto any prohibitions and restrictions with respect to the composition and quality of the explosive and the unloading, landing, delivery, and conveyance thereof and such further restrictions as he may think fit for the protection of life and property.

"Sec. 5. The license shall be of such duration as the Secretary of the Treasury may fix, not to exceed six calendar months, and shall be available only for the person or persons named in the license. It shall contain the provision that it may be revoked by the Secretary of the Treasury at any time.

"Sec. 6. The owner and driver of any vehicle, the owner or master of any ship or boat, and the railroad company or conductor of any railroad car on which any explosive is imported into the United States shall not permit the same to be unloaded and delivered to any person who does not hold a license to import the same from the Secretary of the Treasury.

"Sec. 7. No vehicle or wagon on which explosives are imported into the United States shall contain more than 4000 pounds, including weight of enveloping package, and shall not be transported at a faster gait than a walk. It shall carry a black flag, in dimension at least 3 feet square, displayed so as to be of easy view. An extra man to the driver shall accompany such vehicle or wagon, whose duty it shall be to keep off and warn all persons who are smoking from approaching such vehicle or wagon. If moving in trains, each vehicle in such wagon train shall preserve an interval of at least 75 feet from the preceding vehicle.

"Sec. 8. All ships or boats conveying explosives to be imported into the United States shall carry flags of at least 3 feet square, to be displayed at masthead in the former and at the stern in the latter, black in color when on those plying in fresh water and red for all sea-going vessels, and no ship or boat shall carry more than 50,000 pounds weight of explosives.

"Sec. 9. No railroad car on which explosives are imported into the United States shall carry more than 10,000 pounds, including weight of enveloping package, and the number shall be limited to five, allowed to be attached to any freight train. There shall be at least three empty cars, or cars filled with non-combustible merchandise, preceding or following any such cars loaded with explosives. No explosives shall be imported into the United States on any gondola or open car.

"Sec. 10. In the event of any breach by any act of default of the provisions of the preceding sections, with respect to the importation of an explosive, or of the provisions of any importation license, all or any part of the explosive with respect to which such breach is committed, or being in any vehicle, wagon, ship, boat, or railroad car in connection with which such breach is committed, may be forfeited.

"Sec. 11. The gunpowder of class 1, if to be imported into the United States for private use and not for sale, and in safety cartridges, to the amount of 5 pounds for each passenger, shall not be subject to the restriction imposed by this act.

"If imported for sale and not exceeding 5 pounds, it shall be contained in a substantial case, bag, canister, or other receptacle, made and closed so as to prevent the gunpowder from escaping. If exceeding 5 pounds in amount, it shall be contained either in a single package or a double package. A single package shall be a box, barrel, or case of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure while being conveyed, and will not allow the gunpowder to escape. If it is packed in a double package, the inner package shall be a substantial case, bag, canister, or other receptacle made and closed so as to prevent the gunpowder from escaping, and the outer package shall be a box, barrel, or case of wood or metal, or other solid material, and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow the gunpowder to escape. The interior of every package shall be, whether single or double, free from grit and otherwise clean, and every such package, when actually used for the package of gunpowder, shall not be used for any other purpose. There shall not be any iron or steel in the construction of any such package, unless the same is effectually covered with tin, zinc, or other material. The amount of such gunpowder in any single package, or, if there is a double package, in any one outer package, shall not exceed 100 pounds, and on the outermost package there shall be affixed the word "Gunpowder" in conspicuous characters by means of a brand or securely attached label or other mark.

"Sec. 12. The explosives of class 2 (nitrate mixture) if not exceeding 5 pounds in amount shall be contained in a substantial case, bag, canister, or other receptacle made and closed so as to prevent any explosive from escaping. If exceeding 5 pounds in amount, it shall be contained in a double package, the inner package being a substantial case, bag, canister, or other receptacle, made and closed so as to prevent any explosive from escaping, and the outer package shall be a box, barrel, or case of wood or metal, or other solid material, and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and the amount of explosive in any one outer package shall not exceed 100 pounds. The interior of every one such package shall be free from grit and otherwise clean, and every package when actually used for the packing of one nitrate mixture shall not be used for the packing of any other nitrate mixture or for any other purpose. There shall not be any iron or steel in the construction of any package unless the same is effectually covered with tin, zinc, or other material, and on the outermost package there shall be affixed in conspicuous characters, by means of a brand or securely attached label or other mark, the word "Explosive," with the name of the explosive, followed by the word "Nitrate mixture," and the name and address of the sender.

"Sec. 13. The explosives of class 3 (nitro compounds), if not exceeding 5 pounds in amount, shall be contained in a substantial case, bag, canister, or other receptacle made and closed so as to prevent any explosive from escaping. An explosive of the division 1 of this class, if exceeding 5 pounds in amount, shall be contained in a double package, the inner package being a substantial case, bag, or covering without any metal in the construction thereof, and so made and closed as to prevent any explosive from escaping; and any one of such packages shall not contain more than 10 pounds, and the outer package shall be a box, barrel, or case of wood or other solid material (other than metal), and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape. The inner or outer package or both shall be thoroughly waterproof, and the amount of explosive in any one outer package shall not exceed 50 pounds. An explosive of division 2 of this class, if exceeding 5 pounds in amount, shall be contained in a double package. The inner package being a substantial case, bag, canister, or other receptacle made and closed so as to prevent any explosive from escaping; and the outer package shall be a box, barrel, or case of wood or metal, or other solid material, and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and the amount of explosive in any one outer package shall not exceed 50 pounds.

"An explosive of division 3, if exceeding 5 pounds, shall be contained in a double package, the inner package being a substantial case, bag, canister, or other receptacle made and closed so as to prevent such explosive from escaping; and the outer package shall be a box, barrel, or case of wood or metal or other solid material, and shall be of such strength, construction and character that it shall not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and the amount of explosive in any one outer package shall not exceed 100 pounds. Whatever be the amount of the explosive and to whatever division it belong, the interior of every package shall be free from grit and otherwise clean, and every package when actually used for the packing of one nitro compound shall not be used for the packing of any other nitro compound or for any other purpose, and there shall be no iron or steel in the construction of any inner or outer package unless the same is effectually covered with tin, zinc, or other material. On the outermost package there shall be affixed in conspicuous characters, by means of a brand or securely attached label, or other mark, the word "Explosive," with the name of the explosive followed by the words "Nitro compound," "Division" "1," "2," or "3," as the case may be, and the name and address of the sender.

" Sec. 14. Explosives of class 4 (chlorate mixture), if not exceeding 5 pounds in amount, shall be contained in a substantial bag, case, canister, or other receptacle made and closed so as to prevent any explosive from escaping. If exceeding 5 pounds it shall be contained in a double package. The inner package shall be a substantial case, bag, or covering without any metal in the construction thereof, and so made and closed as to prevent any explosive from escaping, and any one of such packages shall not contain more than 10 pounds; and the outer package shall be a box, barrel, or a case of wood or other solid material (other than metal), and shall be of such strength, construction and character that it will not be broken or accidentally opened, or become defective, or insecure whilst being conveyed and will not allow any explosive to escape, and the amount of explosive in any one outer package shall not exceed 50 pounds. In addition, in the case of an explosive of division 1 of this class, the inner or outer package or both shall be thoroughly waterproof. The interior of every package shall be free from grit and otherwise clean, and every package when actually used for the packing of one chlorate mixture shall not be used for the packing of any other chlorate mixture, or for any other purpose, and there shall not be any iron or steel used in the construction of any outer package unless the same is effectually covered with tin, zinc, or other material. On the outermost package there shall be affixed in conspicuous characters by means of a brand, or securely attached label, or other mark, the word " Explosive," with the name of the explosive followed by the words " Chlorate mixture compound, division 1 " (or 2, as the case may be), and the name and address of the sender.

" Sec. 15. Explosives of class 5 (fulminates) which are of such character that they cannot be packed mixed with water, or that danger would arise from such mode of packing, shall be packed in such manner as shall be specially directed by the Secretary of the Treasury. Any other explosive of this class shall be packed in bags or coverings of calico, canvas, or other material permeable to water, and containing each not more than 25 pounds, and so made and closed as to prevent any explosive from escaping. Such bags or coverings shall be packed in a case containing sufficient water to insure the explosive being kept constantly wet, and such inner case shall be packed in an outer case containing sufficient water constantly to surround the inner case, and both cases shall be of such strength, construction and character that neither will be broken nor accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any fulminate or water to escape, and the amount of explosive in any outer case shall not exceed 200 pounds. Every package when actually used for the packing of one fulminate shall not be used for the packing of any other fulminate or for any other purposes, and on the outer case there shall be affixed in conspicuous characters, by means of a brand or securely attached label, or other mark, the word " Explosive," with the name of the explosive followed by the words " Fulminate, division 1 " (or 2, as the case may be), and the name and address of the sender.

"Sec. 16. Any explosive of divisions 1 and 2 of class 6 (ammunition) shall be contained in a box, barrel, or case of wood, metal, or other solid material, and of such strength, construction and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape, and any one such package shall not contain more than 100 pounds of such ammunition. Any explosive of division 3 of this class shall be packed in a double package. The inner package shall be a substantial case, bag, canister, or other covering made and closed so as to prevent any explosive from escaping, and shall not contain more than 2 pounds of such explosive. The outer package shall be a box, barrel, or case of wood, metal, or other solid material, and shall be of such strength, construction and character that it will not be broken or accidentally opened or become defective or insecure whilst being conveyed, and will not allow any explosive to escape, and any one such outer package shall not contain more than 50 pounds. The interior of every package, whether single or double, shall be free from grit and otherwise clean.

"Every package, whether single or double, when actually used for the packing of one description of ammunition shall not be used for the packing of any other description of ammunition, or for any purpose, provided that with explosives of division 1 of this class there may be packed any article which is not of an inflammable or explosive character, or liable to cause fire or explosion. On the outermost package there shall be affixed in conspicuous characters, by means of a brand or securely attached label or other mark, in the case of percussion caps or safety fuzes for blasting, the words "percussion caps," or "safety fuzes for blasting," as the case may be, with the name and address of the sender, and in the case of any other ammunition the word "explosive," with the name of the explosive, followed by the words, "ammunition, division 1" (or 2 or 3, as the case may be), and the name of the sender; also indicate if cartridges and charges for cannon, shells, mines, blasting, or other like purpose; the name of the explosive material contained in such cartridge or charge shall be given as "explosive blasting cartridge containing dynamite ammunition, division 2."

"Sec. 17. An explosive of division 1 of class 7 (fireworks) shall be contained in a double package. The inner package shall be a substantial canister case, or other receptacle, hermetically closed, and contain no more than 1 pound of explosive, and the outer package shall be a box, barrel, or case of wood, metal, or other solid material, and shall be of such strength, construction and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and any outer package shall not contain more than 20 pounds, and there shall not be any iron or steel used in the construction of any such inner or outer package unless the same is effectually covered with tin, zinc, or other material. An explosive of division 2 of this class exceeding 5 pounds in weight shall be contained in a box, barrel, or case of wood, metal, or other solid material, and of such strength, construction and character that it will not be broken or accidentally opened, or become defective and insecure whilst being conveyed, and will not allow any explosive to escape, and the amount of explosive in any one package shall not exceed 100 pounds. The interior of every package, whether single or double, shall be free from grit and otherwise clean, and when such package shall be used for the packing of fireworks shall not be used for any other purpose, and on the outermost package there shall be affixed, in conspicuous characters, by means of a brand or securely attached label, or other mark, the word "Explosive," and the name of the explosive followed by the words "Fireworks, division 1" (or 2, as the case may be), and the name and address of the sender.

"Sec. 18. The Secretary of the Treasury shall have the power to increase the amount of the maximum weight of any explosive allowed to be contained in any one package imported into the United States as prescribed by the act, such increase of weight to be specified in the body of the importation license granted and to be limited to one shipment and during the period of six months ensuing from the date of such license.

"Sec. 19. All officers of the customs shall have the same power with respect to any explosive imported, and the vehicle, car, ship, or boat containing the same, as they have for the time being with respect to any article on the importation of which restrictions are for the time being imposed by the statutes of the United States relating to such importation, and the vehicle, car, boat, or ship containing the same, and the statutes for the time being in force relating to such importation for any such article, or any vehicle, car, ship, or boat shall apply accordingly.

"Sec. 20. The importation from any foreign country into the United States on any railway car of nitroglycerin, or any fulminate, except the fulminate of mercury, is prohibited, and any person who knowingly ships or attempts to ship the same on any such railway car, for such purpose, shall be deemed guilty of a misdemeanor and punished by fine not exceeding $2000, or imprisonment not exceeding eighteen months, and the articles to be liable to seizure and forfeiture.

"Sec. 21. Every person who forges or counterfeits any license granted or required in pursuance or for the purpose of this act, or willfully makes use of any such forged, counterfeit, or false license, shall be liable to imprisonment for a term not exceeding two years.

"Sec. 22. Nothing in this act shall render liable to any penalty or forfeiture the owner or master of any ship or boat or carrier, or the person having charge of any carriage, for any act done in behalf of this act, if he proves that by reason of stress of weather, inevitable accident, or other emergency, the doing of such act was, under the circumstances, necessary and proper.

"Sec. 23. In the event of any breach by any act or default of the provisions with respect to the importation of an explosive, or of the provisions of any importation license, the owner or master of such ship or boat, and the licensee or person to whom the license is delivered shall each be liable to a penalty not exceeding $500, and to a further penalty not exceeding 50 cents for every pound of such explosive.

"Sec. 24. Where a carrier or owner or master of a ship or boat, on which an explosive is imported from any foreign country into the United States, is prevented from complying with the provisions contained in the preceding sections, by the willful act, neglect, or default of the consignor or consignee of the explosive, or other person, or by the improper refusal of the consignee or other person to accept delivery of the explosive, such consignor, consignee, or other person who is guilty of such willful act, neglect, default, or refusal shall be liable to the same penalty to which the carrier, owner, or master is liable for such breach, and his conviction shall exempt the carrier, owner, or master from any penalty or forfeiture whatsoever.

"Sec. 25. Where a court before whom a person is convicted of any offense in breach of the regulations set forth in the preceding sections has power to forfeit any explosive imported from any foreign country into the United States, owned by or found in the possession or under the control of such person, the court may, if it think it just and expedient, in lieu of forfeiting such explosive, impose upon such person, in addition to any other penalty or punishment, a penalty not exceeding such sum as appears to the court to be the value of the explosive so liable to be forfeited.

"Sec. 26. That all laws or parts of laws inconsistent with any of the provisions of this act be, and the same are hereby, repealed."

This recommendation has been embodied in H. R. 8483, of the 53d Congress, third session, introduced by Mr. Wheeler of Alabama.

"Operations of the Division of Military Engineering of the International Congress at Chicago," *Ex. Doc. No. 119*, 53d Congress, second session, 1894, which is a stout volume of about 1000 pages, liberally illustrated, contains an article entitled "Explosives" by W. R. Quinan (pages 429-441), which is an excellent, though too brief, a review of the progress in the explosive art in the United States during the past thirty years, both from the industrial and military standpoint. It will be very wise for those using Guttmann's book, reviewed below, to supplement it with Quinan's article if they wish to know how widely the American departs from the European practice.

Under the title "The Development of Explosives during the Last Quarter Century" (pages 451-457), Lieutenant Willoughby Walke gives "a brief resumé of the recent development of explosives and the underlying principles upon which their manufacture is based," which, while entertaining, contains nothing new either in statement or treatment.

Under the title "The Applications of Explosive Substances," *The Polytechnic,* **10,** 125-133; 1894, publishes an address delivered by Prof. Charles E. Munroe before the Rensselaer Polytechnic Institute of Troy, N. Y., in which the manifold uses of these bodies in the arts and industries, as well as in war, are set forth and described in a popular manner.

Dr. Edwin Pynchon, under the title "High Explosives as a Means of Propulsion in Aerial Navigation," describes in *Transportation,* **3,** 17-21; 1894, with the aid of a considerable number of cuts, a novel air-ship which he has invented and which depends on the explosion of dynamite for its source of energy.

Speaking of this feature of his invention, he says: "The most important part of the whole device is the mechanism for using high explosives. From the magazine room, which is well forward, there extend rearwards two solid oval or grooved pipes of about one inch calibre, each terminating by passing through the upper edge of a concave detonating plate, preferably made of some copper alloy, which plates are placed one at either side of the stern of the vessel, exterior thereto and near the horizontal center of the ship's weight. Properly prepared cartridges are to be automatically fed to these pipes at suitable intervals by a mechanism similar to that of a magazine gun. The cartridges when delivered into the pipes are to be shot by pneumatic pressure to the outer opening at the rear of the vessel and then exploded in the concavity of the detonating plates by aid of the electric current. It will probably be found that the best results will be attained by having the explosion take place near the center of the detonating plate and but a few inches therefrom. The maximum push will thus be secured by the slight air cushion thus provided.

"In order to secure the natural expansive or explosive effects of dynamite, it has heretofore been detonated by the use of a blasting cap, which is first exploded by electricity, or a fuze, and which, by its explosion, generates both the intense heat and concussion required for the detonation of the high explosive. Considerable heat, or the spark of the electric current, when applied to loose dynamite, which is exposed in the open air, will cause it to ignite and burn, though it is not thus exploded, but 'if, when ignited, it be enclosed in a hermetically sealed vessel with resisting walls, it explodes under the influence of heating' (Berthelot). This is owing to the increase in temperature produced by the retention of the first gases of combustion. Dynamite is also exploded when suddenly heated to a sufficiently high temperature, which is found to be about 420° F. From the above data it is easy to see how dynamite or nitrogelatin may be perfectly exploded without the use of the dangerous fulminate blasting cap. The only requirements would be to first have the explosive encased in a suitable and strong shell or container, and second, to have passing through such cartridge, and imbedded in the explosive, a few strands of fine iron wire which would be heated to a point of incandescence by an electric current of sufficient voltage, say 20 v.

"In using such air-ship, after some degree of ascent and forward motion has been made by use of propeller wheels, a pair of cartridges of low power are caused to detonate. These cartridges are to be fed to their respective tubes, and by a moderate force of compressed air slowly shot through the same. When both cartridges are in proper position for firing a weak electric current is closed, which thereby automatically throws a switch and allows passage through the cartridges of a sufficiently strong current of electricity to fire the same. At the start, when the speed of the ship is moderate, light charges should be used, and said charges increased gradually in size or strength until the maximum speed of the vessel is attained, which may then be maintained by using the maximum charge with such frequency as practice teaches to be best, and which would be more frequent when adverse winds are being encountered than when going with a favorable breeze. As in my suggested plan the propelling power is changed from the forward end of the ship to its stern whenever change is made from use of propeller wheels to use of explosive accelerator, and as it is known that the center of weight should not be far from the center of power, it will probably be found desirable to provide for a certain per cent. of freight or fuel ballast being moved from the middle of the ship toward its stern when such change of powder is being made. In fact, movable ballast will undoubtedly be found of great utility in balancing the ship at all times, no matter what style of propeller is being used.

"In aerial travel the great desideratum is ceaseless and rapid onward motion, and at an altitude of from 500 to 2000 feet the best results should be attained. It is quite probable that a speed of 150 to 200 miles an hour can be easily had, and will, in fact, be necessary in order to insure a commercial success. I have estimated, that with a ship of the size mentioned, after a full speed of 200 miles an hour has been attained it can be maintained by the explosion, every five seconds, of a pair of 60 per cent. nitro-gelatin cartridges, each weighing two ounces. There will thus be required about one hundred pounds of the explosive for each hundred miles of the journey, and the cost, including a very liberal allowance for construction and insulation of the cartridges, should not exceed forty cents per pound. The expense would then be $1.20 per minute, or $72 per hour, being less than forty cents per mile traveled. Three thousand pounds of fuel would thus more than provide for a trans-Atlantic voyage, and the cost thereof should not exceed $1000, which would be inexpensive for a vessel of its probable carrying capacity, which, in addition to fuel and supplies, should easily transport twenty-five adults, consisting of a crew of ten and fifteen passengers. Let man but partially succeed in the field of aerial navigation and there is no doubt but that the maximum of success will follow in much less time than has been required in the evolution of the ocean steamer."

Ex. Doc. No. 20 of the U. S. Senate, 53d Congress, first session, comprises the report of the U. S. Commission on Safe and Vault Construction, which is issued as a volume of 90 pages, illustrated by upwards of 100 cuts and plates. The appendix records the results of the experiments made by Professor Charles E. Munroe and Lieutenant Rodman in attacking safes and vaults by means of nitroglycerin, dynamite, gun-cotton and other explosives.

The experiments were made to demonstrate the relative efficiency of the various systems of construction tested in resisting either "burglarious operations" or "mob violence," it being understood by a "burglarious operation" that the contents of a closed and locked safe should be made accessible within twenty-four hours by the use of materials such as a party of men could smuggle into a bank and which could be used without attracting attention or doing material damage to the surroundings; and by "mob violence," that the vaults are supposed to be in the possession of a mob which has ample time and quantities of explosives at hand, and is indifferent to the noise that is made or the destruction that is wrought, provided the treasure be secured.

Among the many accounts of burglarious operations is one in which a $3000 square laminated safe of the most approved construction was attacked by inserting in the crevice about the locked door 4.8 ounces of nitroglycerin, and in eight minutes after the operation of loading was begun the charge was fired, with the result that the whole of the joint below the door was blown out and a hole made of sufficient size to admit the hand and arm, while the doors and divisions of the interior compartments were completely shattered. On repeating the operation with 4.5 ounces of dynamite the door was torn completely off.

Among experiments made to demonstrate the resistance of structures to attack by a mob was one upon a safe 29 inches cube, with walls 4.75 inches thick, made up of plates of iron and steel. Two charges of untamped dynamite were fired upon the safe. The first charge of 9.5 pounds in weight made a hole three inches in diameter clear through to the interior of the safe, while a second charge of 12.5 pounds enlarged this hole to 5.5 inches.

These dynamite charges were built up in a peculiar way, invented by Professor Munroe. He has stated in these Notes* that he found that when he perforated disks of compressed gun-cotton and detonated these disks in contact with metal, the metal plates could be perforated, though solid blocks of gun-cotton of greater weight failed to effect the perforation of similar plates, and he advanced a theory to account for this action. Acting on this theory when making the experiments before the Safe and Vault Commission, he took a metal can about eight inches in height and of suitable diameter, placed its open mouth downward and bound around it sticks of dynamite so placed that they touched sides; then a solid bundle of sticks was placed on the base of the can and the detonator placed in this. When this hollow cartridge was fired with the open or hollow end "in contact," it was found that plates of metal could be pierced with readiness which would successfully resist attacks by solid charges of the same explosive of many times the weight.

It is believed that this "hollow high explosive cartridge" will eventually find application in warfare, and that by employing it

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* Proc. Nav. Inst., 13, 594; 1887, 14, 771; 1888.

in place of the present expensive methods of testing armor plates in vogue at proving grounds there will follow a gain in speed and reduction in expense without any loss in accuracy or reliability.

Mr. Walter D. Field gives in the *J. Am. Chem. Soc.* **15**, 140-144; 1893, **16**, 487-498, 543-549; 1894, an illustrated account of "Pyroxylin, its History and Manufacture," in which he has collated from the patent literature and elsewhere, memoranda regarding the development of this important industry, and illustrations of the various apparatus employed or proposed.

By the term pyroxylin is understood the soluble nitric ethers of cellulose, namely, the di-, tri-, tetra- and penta-nitrates. From the date of the use of pyroxylin in photography, as collodion, by Scott Archer in 1851, the number of its uses has increased until, at the present time, tons of the lower nitrates of cellulose are produced yearly. In the form of celluloid it finds manifold applications. As a varnish it is used on penholders, pencils, silver and brass ware. Articles are bronzed with it as a medium, and an artificial leather has been produced by its aid which has already found a ready market to the extent of many thousands yards.

The portion of the article which is likely to prove of most interest to the student of explosives is that which is devoted to the variation in the composition of the pyroxylin produced with the differences in the strength and proportions of the acids, the time and temperature of exposure, and the relative humidity during nitration, and also that dealing with the behavior of the product toward solvents.

Dr. J. E. Blomène treats of "The Manufacture of Soluble Nitrocellulose for Nitrogelatin and Plastic Dynamites" in *J. Am. Chem. Soc.* **17**, 411-419; 1895, where, after describing what sort of material is required and giving the method of preparing the cotton, he says:

"As is always the case, where a number of nitro-derivatives can be obtained simply by using a stronger or weaker nitric acid and by changing the conditions under which it is used, the tri-nitrocellulose can be obtained in several different ways. The factors to be taken into consideration are:

(1) The *proportion* of sulphuric and nitric acids used in the mixture.

(2) The *strength* of the two acids respectively.

(3) The *length of time* the acid mixture is allowed to be in contact with the cotton.

(4) The *temperature* maintained during the reaction.

(5) The *construction* of the plant itself; and a number of minor conditions, such as the humidity of the atmosphere at the time of the reaction.

I will simply indicate the importance of each one of these conditions and then describe *one* way, which I have found, after numberless experiments, to give satisfaction; that is, to produce a nitrocellulose soluble in nitroglycerol at a reasonable cost.

If too *much* sulphuric acid be used this is likely to attack the cotton *before* the nitric acid begins to act, converting it partly into cellulose hydrate (this will later be converted into a higher nitration degree by the nitric acid, as it is much more readily acted upon than the cellulose and will then form an insoluble nitrocellulose) and partly into glucose, which will again partly be nitrated to nitrosaccharose, which is insoluble in nitroglycerol and, besides, a very dangerous substance to have present. Again, if too *little* sulphuric acid be present it will soon form its highest hydroxide and be unable to absorb more of the water rapidly formed during the reaction, when the nitric acid will become diluted and be unable to nitrate the cellulose. The right proportion of acid mixture is, therefore, of great importance.

If *too strong* sulphuric acid be used the result will be the same as above-mentioned for an excess of it; if too strong or too weak nitric acid be used it is obvious that a higher or lower nitration degree than the one desired will result. It goes without saying, therefore, that the strength of the acids is of utmost importance.

In the reaction between nitric acid and cellulose no fumes are given off, except what is driven off by the heat (in which it widely differs from several other nitration processes), and although the reaction becomes feebler and, eventually, completely stops, when the acid has been diluted to a certain limit it only gradually diminishes in force, and therefore the time has to be so balanced that the lower nitration degrees have been passed without part of the cellulose having been too highly nitrated when it is stopped. Hence the importance of careful regulation of the time.

If the nitration pots are surrounded with water kept at a constant temperature, it will be found that the quickness and degree of the nitration depend, to a considerable extent, upon the temperature of this water. Thus, if the temperature be kept up to a high degree the nitration will be much more rapid, but at the same time experience has shown me that, in this way, a *mixture* of different nitration degrees is much more apt to result than the uniform nitration from one degree to another. Curiously enough, the same result is obtained if no external heat at all be applied, and accordingly in my experience a carefully maintained temperature of 70° C. has been found to give the most uniform result; but no doubt good, and perhaps more economical results can be reached by elevating the temperature of the surrounding water.

It is within the experience of every chemical manufacturer how much the size and construction of the vessels in which the reaction takes place influence the result, and this is fully as true in this industry as in any other. It is especially so as the cotton is so bulky that it is hard to keep every part of it in contact with the acid mixture. Under otherwise the same conditions I have found quite a difference in the product whether it was made on a clear and dry day, or when the day was rainy or cloudy, the more so as the building in which the operation takes place has to be left open to a great extent to allow the acid vapors to be carried away.

Even in very large dynamite works it is not always practicable to adopt the very best appliances for the manufacture of nitrocellulose, because it must necessarily be only a small part of the plant (an average of two per cent. of the ingredients), and can only be conducted by dependence for labor, material, etc., on other parts of the works. In a large plant for the exclusive manufacture of this kind of nitrocellulose the conditions would be more favorable for improvements.

The acid mixture I have found best to use is the following: Nitric acid of 1.430 sp. gr., free from chlorine and such an amount of sulphuric acid as would influence the specific gravity, forty parts; and sixty parts of sulphuric acid of 1.835 sp. gr. The specifications for acids governing the supply for other parts of the works can be adopted for this. It is self-evident that this proportion of acids is only necessary when the work is carried on as hereinafter described, and can be greatly varied under different conditions. Such an acid mixture as this cannot be stored in iron drums for any length of time and is therefore troublesome to get, if the nitric acid is not manufactured at the works. The nitric acid must be shipped in carboys; the sulphuric acid can be shipped in drums.

In mixing the two acids a sufficient quantity can be mixed at one time to last for two or three days' supply, and then stored in drums, as the acid will hardly, in this short time, affect the iron to any great extent. The mixing is best effected in a wooden tub lined with heavy lead in such a way as to allow a water-jacket of about two inches around it. (A condemned nitroglycerol apparatus with the coils removed answers this purpose very well.) If compressed air be at hand this should be used as a stirrer by placing a small perforated lead coil at the bottom of the tank and letting the air bubble through the mass, since it is very difficult to get any other kind of stirrer that will stand the acids. The men should be warned to have the earthenware faucet at the bottom of the tank well greased, to tap it very gently, to always use their rubber gloves, and to have an ample supply of water close at hand.

This mixture, although carefully made from acids of 1.430 and 1.835 sp. gr. respectively, will vary in specific gravity from 1.678 to 1.682, but if below or above this, some mistake has been made in the mixing or stirring. The nitric acid should always be dumped in the tank first and the sulphuric acid afterwards, so as to give the latter a chance to mix by gravity as much as possible. Just before using, the acid mixture should be stirred again. For this purpose it is convenient to have a lead-lined tank, with an air-stirrer, of a size to hold one charge for the nitrating pots in use, in which the mixture is stirred up thoroughly and then drawn off for each pot as rapidly as possible.

The arrangement of the nitration pots, of course, must depend on existing conditions, such as size and form of the building, the size of the pots, the material used for confining the water around them, the supply of water of suitable temperature, etc. Under ordinary circumstances I have found it practicable to use earthenware pots sixteen inches deep and thirteen inches in diameter, enclosed in wooden troughs twenty feet long by twenty inches wide, connected by means of leaden pipes. If shorter it is a waste of lumber, if longer they are likely to leak from the pressure. If the troughs can conveniently be made from concrete or brickwork with water-tight mortar, of course they can be extended to any desired length.

Experience has shown two pounds to be the right amount of cotton to be used in one nitration pot. To save time and labor it is important to nitrate as much as possible at one time, but the necessity of getting a uniform product limits the amount; and as the cotton clogs or packs together as soon as wet by the acid mixture, only so much can be used at one time as will allow the mixture to act uniformly on the whole bulk of the cotton, without nitrating the outer portion too much and the inner portion too little. After having tried different amounts I have reached the conclusion that (under the given conditions) two pounds is the maximum that can safely be treated in one nitration pot.

Forty-five pounds of well-stirred acid mixture is weighed out and placed in the pots, which are surrounded by water heated to 70° C. The two pounds of cotton for each pot should be previously weighed out, and ready to be put in so as to have this done as nearly simultaneously as possible. It is now immersed in the acid mixture, turned about a few times with a fork and kept down by a perforated cover. The only reason for using such an excess of acids is that the cotton must be covered by it; if good covers are used, forty pounds or less is enough. Besides the perforated covers, each pot should be provided with solid overlapping covers to keep back the fumes. It is now left for one hour and ten minutes, except that after thirty-five minutes the cotton is quickly turned about with the fork a couple of times and the covers replaced. After this the nitrated cotton is quickly taken up, squeezed with the fork and wrung out in a centrifugal machine. From this it is taken to a large-sized tank well filled with cold water, where it is thoroughly washed. It should be kept in this tank in running water for about one hour. It is well to have a large quantity of water to prevent heating by adherent sulphuric acid, but it is not so important as in the case of gun-cotton, because it is not so easily ignited by the heat generated, nor is the acid as strong as in the latter case. It is then transferred to another tank of the same size. This is conveniently placed below and the nitrocellulose transferred on a wooden slide. Here it is washed in a sal-soda solution. From this it is taken to a pulping machine or hollender, where it is reduced to a fine pulp. This part of the process is of the greatest importance, as it has been proven time and time again that if insufficiently pulped it is hard, if not impossible, to dissolve it in nitroglycerol. I have found that nitrocellulose which had before been rejected as insoluble, worked very well after it had passed two or more hours in the pulp machine. From the pulp machine it is emptied into a large tank, allowed to settle, and the water filtered off. It is then passed either through a centrifugal machine or a hydraulic press, and thus freed from water as far as possible. It is spread in drying boxes to a depth of about two inches and kept at a temperature of about 80° C. till thoroughly dried. After that it is rubbed through fine screens until as fine as the finest flour. If treated in this way the nitrocellulose will dissolve very quickly in nitroglycerol. Seven per cent. of nitrocellulose dissolves in ninety-three per cent. nitroglycerol in less than twenty minutes to a transparent jelly, and three and five-tenths per cent. gives the nitroglycerol the consistency of syrup. Several hundred analyses of nitrocellulose prepared in this way show it to contain from 20.5 to 21.8 per cent. of NO_3, which very nearly corresponds to the formula of trinitrocellulose. The process carried out in this way is simple and requires no great skill or experience. The cost under ordinary circumstances and with conscientious supervision varies between thirty-five to forty cents a pound. The spent acid must, of course, be taken care of either by regaining it or by using it direct for other chemical processes."

Under the title of "The Manufacture of Smokeless Powder," Oscar Guttmann gives in the *J. Soc. Chem. Ind.* **13**, 575-584; 1894, a description of the methods employed, with illustrations of the apparatus used, generalizing his methods as one is compelled to when so many competitors are in the field and all the processes are so new. The description is preceded by a historical resumé of these powders, and succeeded by a general statement as to their properties and advantages, together with a profitable discussion such as characterizes the meetings of British scientific societies. The author does not often indulge in criticism, but he seems to have fallen into error in his remarks on the formation of indurite. Altogether, the paper is a valuable one, as the former articles by this author have been, and it is worth reading in full, and critically.

English Patent No. 6129, April 9, 1891, has been granted the Dynamite Actiengesellschaft Nobel of Vienna, for "Improvements in the Manufacture or Production of Gunpowder or like Explosives," the object of the invention being the manufacture of a smokeless powder from nitrocellulose without having added substances which dissolve or gelatinize the nitrocellulose.

For this purpose nitrocellulose in a state of fine meal is mixed with di- or tri-nitro derivatives of benzene, toluene, xylene or naphthalene, the proportions of nitrocellulose to the nitro derivatives depending on the projective force required, varying from 99 to 70 parts by weight of the former to 1 to 30 parts by weight of the latter.

The Boston *Herald* of September 6, 1894, announces that one of "the largest blasts of dynamite that has ever taken place in a quarry occurred at 5 o'clock last evening at the Palisades quarries, about a mile and a half from Fort Lee, New York.

Two shafts were sunk in the face of the palisades, about 65 feet in depth, and into each shaft fully 1500 pounds of dynamite were placed.

When everything was in readiness, the connections were made and the mountain was shorn of about 1200 feet of surface. This displacement extended about 500 feet, on an average, into the rock. The weight of the rock displaced is estimated at 80,000 tons.

The shock was felt at Fort Washington, directly across the river, owing to the stratum of rock which extends to that point."

Among other large blasts we may note that occurring at this same Fort Lee quarry in 1893, in which 4000 lbs. of dynamite were fired and 100,000 tons of rock removed, and the one occurring the same year at the Dinorwic quarries, Llanberis, when 2½ tons of gelatine dynamite were used in the charge and 180,000 tons of rock were displaced.—*Ann. Rept. H. M. Insp. Exp.* for 1893, p. 74.

The New York *World,* February 3, 1892, reports an explosion of alcohol vapor which occurred at Rummel Company's hat factory, Newark, N. J., on February 2, and through which three men were killed and two wounded, while the building, a large two-story one, which had been recently erected, was unroofed, its side walls were shattered, and the glass in the windows of this and the surrounding buildings for a considerable distance about was destroyed. The description of what occurred is very vague, but it appears that a new machine called an alcohol condenser had recently been erected in the factory; that on the day of the accident it was out of order, and that, at the time of the explosion, a plumber was at work repairing it. As 158 men and women were at work in the building at the time of the explosion, it is remarkable that the casualties were so light.

On the evening of March 9, 1893, a startling explosion occurred in the freight station of the Midland Railway at Whitecross Street, London, which, being seemingly due to a mysterious agency, gave rise to considerable anxiety and led to an investigation the following day by Col. Majendie, H. M. Chief Inspector of Explosives, and Dr. A. Dupré, Chemist to the Home Office.

The results of this investigation are given by the latter in *J. Soc. Chem. Ind.* **13**, 198-200; 1894, under the title of "Note of an Interesting Explosion caused by Sodium Peroxide," in which it is shown that when this powerful oxidizing agent, which is now being manufactured on an extended scale, is mixed with wood meal, shavings, hay, cotton, wool, sulphur, bisulphite of sodium or other combustible bodies, the mixture is set on fire or exploded by simply moistening with water. In fact, a slightly rough deal board may be set on fire by merely covering it with a layer of peroxide and dropping water on it. When once the combustible has taken fire a very fierce combustion results so long as any peroxide is left, the effect being greatly enhanced by the melting of the peroxide, which, wherever it flows, sets fire to everything combustible. Hence sodium peroxide differs from most oxidizing substances in the fact that its power is developed by either fire or water.

These properties of the peroxide present a fresh danger to carriers. In the accident investigated, sodium peroxide was found to have been present, and it had apparently become wet by some solution of a sulphur compound packed with it. If the peroxide is put up, as it easily may be, in hermetically sealed tins and packed in mineral wool or infusorial silica, its transportation is without danger.

The attention of hygienists has been called to the consideration of "Modern Explosives in Relation to Health," owing to the fact that within recent years complaints have been made by those engaged in coal and other mines, where modern "high explosives" were used for blasting, that the fumes resulting from the explosion of these bodies produced deleterious effects, hence, in compliance with the wish of the workpeople, a committee was appointed in September, 1889, by the Durham Coal Owners' Association, consisting of representatives of both masters and men, with two of H. M. Inspectors of Mines, to consider the question, and report whether the fumes produced by the combustion of tonite and roburite were injurious to health, power being given to the committee to call in professional advisers. Mr. Thomas Bell, H. M. Inspector of Mines, was appointed chairman; Professor P. Bedson, chemical adviser, and Drs. Drummond and Hume, medical experts.

Trials were made with tonite, roburite and gunpowder at several collieries, the experiments being conducted in the following manner: First, samples of air were taken at the intake and their composition ascertained by analysis. Then, during the firing of the shots, samples of the vitiated air were taken at the return. The apparatus used for the collection of these samples consisted of a zinc aspirator of about 600 cubic inches' capacity, which, having been filled with water, was slowly emptied, so that the time occupied in displacing the water completely by air was about an hour. The vessel was then securely sealed. A second quantity of air was taken in a glass pipette a quarter of an hour after starting the aspirator, and half an hour after a sample of air in a bottle of 30 cubic inches' capacity was collected, in which the amount of carbonic acid was subsequently determined. The air containing the fumes produced in the immediate vicinity of the shot-firing was collected in a different manner, after unsuccessful attempts had been made to obtain representative samples by means of the zinc aspirators. For this purpose large brass cylinders were employed, 24 inches long and 6 inches in diameter, with a capacity of about 680 cubic inches. At one end of the brass cylinders were two apertures, terminating in narrow brass tubes, securely closed by glass plugs fixed in pressure tubing. These cylinders were first exhausted by an air-pump and then closed in the manner described, being tested carefully with a mercury gauge before each experiment to see if the vacuum had been maintained. A sample of the fumes produced was collected immediately after the firing of the shot by opening a clamp closing one of the apertures to the cylinder, by which means it was quickly filled.

A glass tube filled with glass wool, through which the gases passed before entering the cylinder, removed all solid matter from the mixture of air and gases resulting from the explosion. Naturally, the proportion of air to fumes collected in this manner must vary considerably with different experiments, as the time occupied in reaching the scene of the explosion, and the rate of the air-current through the mine, both influence the rate of diffusion of the fumes. The samples taken for the estimation of carbonic acid, both at the intake and at the return, were examined immediately on reaching the surface. The other two samples of air collected at these two places served—(*a*) the one collected in the pipette for the estimation of the oxygen, and (*b*) the sample taken in the zinc aspirator for the complete analysis of the air. Similarly, the samples taken in the brass cylinders at the shot-firing district were used for the determination of oxygen, nitrogen, carbonic acid and also for other gaseous bodies, while smaller samples taken in exhausted pipettes were used for determining the ratio of carbonic acid and of oxygen to nitrogen. These experiments lead to the following conclusions:

The roburite used consisted of a mixture of chlorodinitrobenzene with ammonium nitrate. Three sets of experiments were made with it. (1) The roburite was fired by Bickford's fuze. In all twenty-three shots were fired, there being a total weight of 5.5 pounds of the explosive. Samples of air were taken at both the intake and the return. During the shot-firing four aspirators were filled to examine the fumes. The fumes from four shots were tested especially with blood for carbon monoxide, with negative result. Special examination of the contents of the aspirators for carbon monoxide, nitric oxide and hydrochloric acid showed that all these deleterious gases were absent. A mouse was suspended in a cage in the return during the whole time and subsequently drowned; a spectroscopic examination of its blood gave no indication of carbon monoxide. (2) At the second visit, again twenty-three shots were fired, having a total weight of 4.7 pounds. Samples were collected as before. The air at the return, and the fumes, both showed traces of carbon monoxide. The method used for testing and estimating the CO on this occasion consisted in passing the air through a solution of palladium chloride, which is reduced by carbon monoxide, with the precipitation of metallic palladium. The samples in the brass cylinders from the neighborhood of the shot-firing showed, when examined by this method, amounts of CO varying from 4.2 to 1.9 parts per 10,000 parts of air, or 0.042 to 0.019 per cent. (3) On the third experiment roburite and gunpowder were tried together, roburite being fired from three places and gunpowder from three places. In all, six charges of the former were fired, weighing 2.25 pounds. The samples taken in the return showed no indication of carbon monoxide, but the fumes, which on this occasion appeared to clear away but slowly, contained CO, the amount being 24 volumes per 10,000 in one sample collected on the face of the coal in the midst of the fumes. A second sample collected on the fumes beginning to lift gave only 1.4 volumes per 10,000, or .014 per cent., thus showing that the air-current acts immediately in clearing away the fumes.

The tonite consisted of equal parts of gun-cotton and barium nitrate, intimately mixed and compressed into cylindrical cartridges with a cylindrical hole at one end. In firing, the cartridge was surrounded by a so-called flame-extinguishing mixture packed in a brown paper bag. As before, Bickford's fuze was used for firing. Two sets of experiments were made, both at South Hetton. On the first occasion nineteen shots were fired, being 6.29 pounds of tonite. The arrangements for collection of the samples were similar to those in the roburite experiments. Examination of the blood of a mouse exposed to the return air showed the presence of CO, but this was the only indication obtained on this occasion of the presence of any deleterious gas. Traces of some combustible gas, either CO or CO and marsh gas, were found in both the intake and return samples. At the second visit thirteen shots were fired, weighing 4.43 pounds. Three cylinders and four pipettes of the fumes were collected. The samples were examined for CO by aspiration through palladium chloride. The results showed it to be absent in the intake air, present in traces in the return, while amounts from 1.9 to 4.8 parts per 10,000 were found in the fumes.

Gunpowder.—Two sets of experiments were conducted with this explosive, one alone and the second in conjunction with roburite. (1) Twenty-six shots were fired, representing 7.38 pounds of gunpowder. A distinctive feature of these experiments was the marked visibility of the fumes produced, as compared with those from tonite and roburite. There was also the characteristic odor of sulphuretted hydrogen. Traces of CO were found in the fumes and also in the return air. (2) These experiments with gunpowder were conducted simultaneously with a series with roburite, so as to obtain fumes from each produced under the same circumstances. It was found in the experiments conducted at Haswell that, owing to the increased air-current, the samples of fumes were more diluted with air than those obtained in previous experiments. Hence a second series became necessary. Six shots were fired, representing 3.33 pounds of gunpowder. No CO was found in the intake air, and only traces in the air from the return and the fume samples.

As previously stated, the solid matter of the fume was filtered from the gaseous constituents by means of glass wool. On analysis it was found to consist for the most part of finely divided coal. In the case of roburite no indication of the presence of nitrobenzene was observed in the solid matter of the fume. In some of the experiments after firing roburite an odor of bitter almonds was noticed, but beyond this no evidence of the presence of nitrobenzene or a similar body was obtained. The presence of carbon monoxide in the fume, which is not a constituent of the complete combustion of tonite and roburite, was shown to be partly due to the burning of the fuze. Some may also be formed by the passage of the heated carbonic acid over the coal. Analysis of the tonite and roburite used showed them to have the following composition:

TONITE.	No. 52.
Barium nitrate	48.21
Potassium nitrate	1.77
Gun-cotton	49.21
Moisture	1.58
	100.00

ROBURITE.	No. 50.	No. 51.
Moisture	1.14	0.66
Ammonium nitrate	83.35	86.30
Chlorodinitrobenzene (sol. in ether)	11.67	11.74
Matter (insoluble in ether and water)	3.14	1.09
Fixed residue	0.70	0.21
	100.00	100.00

No. 51 is a sample of roburite of more recent date than No. 50. Apparently now more ammonium nitrate is added.

The medical report by Drs. Drummond and Hume shows that although they inquired into every case of suspected illness produced by exposure to the fumes, they could find no evidence of acute illness being caused. Of the shot-firers examined only one made any serious complaint, and apparently the dyspepsia from which he suffered was existent before his working with the explosive.

The general conclusions arrived at by the experts were that (1) the fumes produced by tonite and roburite are not more dangerous than those from gunpowder; (2) nitrobenzene is apparently not produced by the combustion of roburite; (3) the carbon monoxide produced is present only in traces; (4) an interval of five minutes should be allowed to elapse before the hewers re-enter the scene of firing; and (5) that, as a portion of the gases in the fumes comes from the fuze, the charges should be fired by electricity.

A more modern explosive than roburite, and one which is similar in nature, is the new "ammonite." The main work of the committee was over before the introduction of this new body; otherwise, in view of the probable general use of ammonite for blasting, it would have been interesting to have examined the fumes produced by its combustion. Ammonite contains 81.5 parts of ammonium nitrate and 8.5 parts of mononitro-naphthalene. It is of equal projectile force to roburite, and superior to tonite. It cannot be exploded by concussion, and burns quietly on an ordinary fire. Its properties are not affected by freezing. It requires rather a strong detonator to produce explosion.—*Industries,* **11**, 182; 1891.

It may be noted here that carbon monoxide, CO, is the most objectionable of the gases found in the products of incomplete combustion or explosion, since as, when inhaled, it combines with materials in the blood corpuscles to form a compound which prevents the blood from performing its proper functions, it exerts a distinct toxic effect. The presence in the atmosphere of one-half of one per cent. of carbonic oxide, or even less than one-half of one per cent. under certain conditions, is fatal to animal life.

Under the title "Les Explosifs Industriels, Le Grison et Les Poussières des Houille,"* M. J. Daniel has collected a large mass

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* Lg. 8vo. Vol. I, 348 pp. Vol. II, 444 pp. Whittaker & Co., London, 1895.

of useful and interesting information from original sources which he very properly cites, but while aiming to produce a work useful as a guide to young engineers in the practice of mining, he has dwelt more fully upon the details and theories of explosives than is necessary in a practical guide, and yet not with sufficient fulness for a treatise on explosives, while space is also occupied by irrelevant descriptions of torpedoes, pneumatic guns and other devices. Being a Directeur de la Compagnie des Explosifs Sécurite, M. Daniel is naturally at his best in his discussion of the composition, properties, tests and applications of these recent explosives, and those interested in the preparation or use of flameless explosives, or in the controversy going on between the promoters of the different products offered, will find this part of the work of value. This book bears testimony to the fact that the producers of these French works have not yet discovered what a convenient and labor-saving device an index is.

"The Manufacture of Explosives"* is the title under which Oscar Guttmann presents his new work, which is issued in two large volumes with 328 illustrations. The arrangement of this book is one which has been made familiar in Désortiany's *Traité sur la Poudre*, and like this work, Guttmann's first volume is devoted partly to the manufacture of "Black Powder" and partly to a description of the raw materials used in the manufacture of the explosive substances. Volume II treats of gun-cotton, nitroglycerin, dynamite, nitro-substitution explosives and smokeless powders, while a considerable space is given to apparatus for testing the velocity, pressure and power of explosives, the whole being followed by some seventeen pages of a bibliography which is far from being exhaustive. From his occupation as a builder of works and inventor of apparatus for use in the manufacture of explosives, Mr. Guttmann has had excellent opportunities for becoming familiar with the art, but it is not to be expected that much will be published in such a work that has not already been made accessible in periodical or patent publications, so that the work is to some extent historical and suggestive. It is in this light that this work is most valuable to American readers, but it fails to describe American methods and products, though they differ materially from those in vogue in Europe.

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* Lg. 8vo, 283 pp. E. Bernard & Cie., Paris, 1893.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

A MESSENGER-PIGEON SERVICE FOR NAVAL PURPOSES.

By Ensign Edward W. Eberle, U. S. Navy.*

During the absence of Professor Marion in the summer of 1895, the writer of this paper was in charge of the homing pigeons of the U. S. Naval Academy loft; and, in October, a report, from which the following paragraphs are taken, was made to the Superintendent of the Naval Academy:

"2. During the summer eighteen pigeons made a total of one hundred and ten flights. The long-distance flight of the summer was made by a pigeon that was released from the U. S. S. Monongahela when one hundred and two miles off Cape Henry, or about two hundred and fifty miles from the home loft. This pigeon was out over night, and it had about twelve hours of daylight from the time of its liberation to the time of its arrival at the home loft, thus making an average of about twenty-one miles per hour for the two hundred and fifty miles.

3. In the swiftest flight of the summer the pigeon was liberated at Norfolk, Va., and arrived at the home loft three and three-quarter hours later, thus making an average of forty miles per hour for one hundred and fifty miles.

4. In previous years it was the practice to fly the pigeons in the Chesapeake Bay from the neighborhood of the Virginia Capes to the home loft, and, consequently, the pigeons were not familiar with the coast-line north of the Virginia Capes.

5. During this summer pigeons were liberated at different points off the coast of Delaware and New Jersey in order to see if

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* The writer of this paper desires to thank Professor H. Marion, of the Naval Academy, for much valuable information on the subject of homing pigeons.

they would mistake Delaware Bay for the Chesapeake, and also to record their times of flight from points off a coast unfamiliar to them. In all of these trials the pigeons returned to the home loft, and some of them made very good records, considering the fact that they had never flown along that portion of the coast.

6. Pigeons that were liberated from the U. S. S. Bancroft when forty miles off the Fenwick Island Shoal, made their first flights to the home loft in twelve hours of daylight. If they flew across Delaware and eastern Maryland in a direct line for Annapolis they averaged about twelve miles per hour; but if they flew down the coast and then up the Chesapeake Bay, they averaged over twenty miles per hour for two hundred and fifty miles.

7. Pigeons liberated from the Bancroft when fifty miles off Cape May made their first flights to the home loft in eleven hours of daylight. If they flew across Delaware Bay, Delaware, and eastern Maryland in a direct line for Annapolis they averaged about twelve miles per hour.

8. These results are very good when it is considered that the pigeons had never flown along that portion of the coast, and had never flown across Delaware or eastern Maryland, or in the neighborhood of Delaware Bay.

9. A pigeon that had made one flight from off Fenwick Island Shoal was liberated from the Bancroft three weeks later when fifty-five miles off Atlantic City, with the result that it increased the speed of its previous flight by about seven miles per hour.

10. I conclude, from these trials, that pigeons can be trained in a short time to fly from points off a coast that is unfamiliar to them.

11. Five pigeons were taken to Gardiner's Bay in the Bancroft and there put on board the yacht Medusa. After the Medusa sailed from Gardiner's Bay the pigeons were kept below decks in a small basket, and after eight days of bad weather at sea one pigeon was liberated off Winter Quarter Shoal and it arrived at the home loft nine hours later. This pigeon had been away from the home loft for twenty-two days, and it had never flown along that portion of the coast. If this pigeon flew in a direct line across Delaware and eastern Maryland it averaged about twelve miles per hour; but if it flew down the coast and up the Chesapeake, it averaged about twenty-two miles per hour for two hundred miles.

13. The flights of the pigeons of the Naval Academy loft have been of an experimental character, and much more satisfactory results might be obtained from a station located on the coast. By regular and systematic flights over a limited portion of the coast, homing pigeons can be so trained as to form a most reliable and rapid method of communication between ships off the coast and the home station.

14. In time of peace the messenger-pigeon service could be made very useful in many ways, and thus the pigeons could be kept in constant training, so that in the event of hostilities they would be in readiness to render valuable service to our cruisers.

15. The messenger-pigeon service would be especially valuable in the event of hostilities with a government that has possessions near our coast; for then our swift cruisers could scout along the enemy's coast and still be in constant communication with the home station, thus keeping the commander-in-chief informed of all movements of the enemy.

16. On account of the distance from the sea-coast, the Naval Academy could not be made valuable as a pigeon station except for breeding and experimental purposes.

17. As the Navy Department has not undertaken the establishment of a messenger-pigeon service, I have not, in this report, proposed a system for establishing stations or for training the pigeons; and I have not enumerated the many valuable results that could be obtained, both in time of peace and in time of war, from this service."

* * * * * * * * * * *

Since the above report was written, two very interesting flights have been made from the U. S. S. Amphitrite, at anchor in Lynn Haven Bay—a distance of one hundred and twenty-five miles from Annapolis. At 9.15 A. M., December 7th, two pigeons were liberated from the Amphitrite, and they arrived at the Naval Academy loft, in the afternoon, with messages from Captain W. C. Wise, U. S. N., as follows:

To Rear Admiral Bunce, Navy Yard, New York:

Amphitrite anchored in Lynn Haven Bay waiting for favorable weather for target practice. Delayed by a snow-storm.

To Prof. Marion, Naval Academy:

My compliments, and wishes that this very valuable service be greatly encouraged by the Government. I deem it of great importance, and will do anything in my power to help it.

As the Amphitrite was not within telegraphic communication, the pigeons were sent with messages, and, although very unfavorable weather prevailed at the time of liberation, they arrived in very good time.

The message for Admiral Bunce was telegraphed to the Navy Yard, New York.

When reviewing the results of these flights made by the pigeons of the Naval Academy loft, the fact must be remembered that the pigeons have not been kept in training. The only opportunities for exercising them in long flights have been from the practice ships during the summer months, and from the Government vessels that have occasionally visited Annapolis. Consideration should be given to the fact that these birds had not previously been set free from positions at sea north of the Virginia capes, and that the trials were made for the purpose of determining whether or not homing pigeons, if liberated off a coast with which they are unfamiliar, can find their way to the home loft within a reasonable time. In all the first flights the homers did fairly well, and in the few second flights over the same general route the time was much decreased.

During good weather a trained pigeon will fly successively over the same general route at a speed of forty to fifty miles per hour. In fact, the remarkable speed of seventy miles an hour has been made. Moreover, the messenger can be relied upon to reach home in all kinds of weather. Pigeons trained for flying over the land have frequently made from four to five hundred miles in one flight, and it is reasonable to suppose that they may be trained to fly about four hundred miles over water. The ordinary flights should prove more reliable over water than over land, because the messenger cannot be tempted to loiter with other pigeons or to stop for food. It might be well to have a reserve of the best pigeons for very long flights from sea, say from 200 to 400 miles. Such birds would necessarily be released in the morning, and it would probably be of service to train them at gradually increasing distances by always releasing them in the morning, so that their uniform habit at sea would be to fly away from the sun (or towards it in Pacific waters) when first set free. Four hundred mile flights over water would seldom be necessary, and two hundred miles off the coast would probably be the limit of reliable and swift flights, while the majority would be under one hundred and fifty miles.

Throughout Europe, thousands of messages are sent daily by pigeon post, and the regularity of the speed over established routes is remarkable. Each important naval power maintains, as well, an efficient messenger-pigeon service for the use of its navy. Many such pigeon stations are located along the coast of France, Spain, and Italy; and Great Britain has a very efficient station at Gibraltar. Homing pigeons have been used with excellent results during French naval manœuvres, having been released from ships under conditions such as appertain to actual warfare and made good flights, thus showing that they are not seriously frightened by the firing of heavy guns. For example, on one occasion pigeons were released from a flotilla of torpedo boats during an attack on the Squadron of the North, when off Brest, and the messages were received at Brest in the usual time for the distance covered. There are many private lofts in the United States, but the pigeons cannot be used for naval purposes because they are not trained to fly over sea, and because their home lofts are not located at desirable points. In the event of hostilities, our cruisers employed on scouting or patrol duty off the coast would have to leave their stations and steam to land when necessary to send important information to the Navy Department.

First-rate naval powers, more especially those with long stretches of coast-line, realize the importance of using vessels as scouts in time of war. Fast merchant steamers of large coal capacity are well fitted for scouting purposes. A proper organization of such scouting vessels into a scouting division would prove a particularly valuable aid to a fleet of battle-ships and to the military stations along the coast. It may be remarked that a small fleet of battle-ships with an efficient scouting service, by using its information to decide when to strike and when not to strike, can so baffle and worry a superior enemy, which it cannot actually defeat on equal terms, as to keep him always on the defensive—pursuing a Fabian policy adapted to the sea.

In the event of hostilities between two nations of equal naval strength, the one that has the more efficient scouting division will have the advantage, more or less decided according to the greater or less superiority of this division. In order to obtain the best service from scouting vessels, it is necessary that they should have rapid and reliable communication with the shore from various distances at sea, and the only way of accomplishing this is by means of homing pigeons. The nation that has a number of twenty-knot cruisers of large coal capacity, and homing pigeons trained to make swift flights from various distances off the coast, will have an ideal scouting division.

A period of eighteen months or two years will be necessary to establish an efficient messenger-pigeon service for naval purposes. The pigeons must be confined at the new stations for about one year in order to make them forget their old home or homes, and to acquaint them with their new surroundings. Then they must be trained to fly to the home station from positions off the coast, beginning with short flights and gradually increasing the distance. By constant practice for six months the pigeons could probably be relied upon to average thirty-five miles or forty miles per hour for distances of one hundred and fifty miles. The most satisfactory results would be obtained by flying the pigeons over a limited portion of the coast-line; that is, having a station located on or near the Atlantic seaboard, fly the pigeons of that station from positions as far off the coast as desired, but within certain limits of latitude—say about seventy-five miles north and south respectively of the latitude of the station. By this system the pigeons of each station could be made very familiar with one hundred and fifty miles of the coast-line, and our entire seaboard would be divided into equal sections, with a station in each located near the middle point. When released from a ship at sea, pigeons fly in the direction of the nearest land, and it is almost imperative that they should be familiar with its appearance. For the benefit of stragglers, the pigeon lofts along the coast should be of the same color and construction, so that if a messenger loses its bearings and is unable to find its own loft it will probably find and go to another, whence the message will be forwarded by telegraph. Two divisions of the messenger-pigeon service thus organized, one on the Atlantic and one on the Pacific coast, would certainly be very useful.

The naval pigeon stations should be located on or near the coast at well fortified points, or at points inaccessible to an enemy's war vessels. They might be connected directly by telegraph; and they should certainly be connected with Washington and the various naval stations, and with all military stations and cities on the seaboard. Our most important stations would be those on our coast nearest adjacent foreign territory, for, in the event of hostilities with a government having such possessions, our fast cruisers could scout the enemy's coast, keeping a constant watch on the ports used as rendezvous for the enemy's fleets, and still be in communication with the home station. Our most important stations on the Atlantic coast would thus be at Key West, little over two hours flight from Havana, and in the neighborhood of Bar Harbor, Maine. Our most important station on the Pacific coast would be at Port Townsend or at Port Angeles, State of Washington, only one hour's flight from Esquimault.

Charts should be made containing the locations and ranges of the pigeon stations, so that plotting the ship's position on the chart will immediately show which pigeons may be flown from that position. For example, the pigeon chart would indicate that Norfolk pigeons could be flown from positions off the coast between the parallels 38° 05′ N. and 35° 35′ N., or in other words, between the parallels seventy-five miles north and south respectively of Norfolk. To avoid confusion and loss of time in the selection of messengers, the pigeon cote for a ship should be so constructed as to have a small compartment for each station on the coast, and the number or name of a station, as well as its limiting latitudes, should be stamped on the door of the corresponding compartment. A ship about to leave port for a cruise between New York and Norfolk would receive baskets of pigeons by express from New York, Norfolk, and the intermediate stations, and these pigeons would be put at once in the proper compartments of the cote. When a pigeon arrives at any station, its message should be telegraphed at once to the proper destination.

An efficient messenger-pigeon service could be obtained by locating stations on the Atlantic coast at or near the following points: Bar Harbor, Boston, Chatham (Mass.), Newport, New York, Delaware Bay, Norfolk or Fortress Monroe, Beaufort (N. C.) or Cape Lookout, Port Royal, St. Augustine, southeast coast of Florida, Key West, Tampa, Pensacola, Port Eads and Galveston. On the Pacific coast: at Port Townsend or Port Angeles, Astoria, Empire City (Oregon), Cape Mendocino or Eureka, San Francisco, Port Harford, Wilmington (Cal.), and San Diego. By this system a ship would be within range of a pigeon station from any position along the coast. The above places have railway communication, so that the pigeons could be sent rapidly to any port along the coast; and even in time of peace all government ships cruising along the home coast should have pigeons on board, so as to be able to report accidents, wrecks, and progress of the cruise. Pigeons have been confined on board ships for over thirty days, and when released have made good flights to the home loft. They should occasionally be released from ships during target practice in order to accustom them to the conditions of battle.

In peace times the pigeon service could be made very useful in many ways other than those mentioned, and the pigeons could thus be kept in constant training. They would be very useful to the Light House Service, being taken by the lighthouse supply vessels and left at the lighthouses and lightships, to be used as necessity or pleasure might demand. During the severe weather of the winter months, the pigeons would often be found especially useful to lightships and life-saving stations for the purpose of reporting wrecks, ships in distress, accidents, or lack of supplies. Cable communication with lightships is frequently interrupted, and pigeons may become the only practicable messengers. They would be taken to the lightships at least once a month and there kept in proper cotes until despatched on service.

A regular pigeon service is in use between Sable Island lighthouse and Halifax, a distance of about one hundred and fifty miles. This service would become very useful to Halifax in case of the approach of a hostile fleet. If the cruises of government vessels along the coast are not frequent enough to keep the pigeons in training, they may be flown from steamers engaged in the coastwise trade. Government cotes could be put on board, though baskets would suffice, and the captains of the steamers would probably be very glad to practice the birds, being fully repaid for their trouble by having at hand reliable messengers for reporting accidents, delay of the vessel, or need of assistance.

In time of hostilities we would find much difficulty in protecting the cities along our extensive coast-line, even if we possessed a naval force as large as that of Great Britain or France. It would not be wise to scatter our battle-ships and armored cruisers along the coast and thus be so weak at every point as to be unable to attack or withstand an enemy's fleet. Our probable plan would be to concentrate the battle-ships and armored cruisers at two or more strategic points, to station monitors and torpedo-boats at various ports, and to use the fast cruisers for patrolling and for destroying the enemy's commerce. The coast-line would probably be divided into sections, and cruisers of the Columbia and Cincinnati type would be used for patrolling these sections, thus forming a continuous picket line. In order that the patrol vessels or scouts may perform efficient service, they must have reliable pigeon communication.

A large fleet of battle-ships, armored cruisers, and protected cruisers approaching the coast to make an attack on a fortified port, or in search of a hostile fleet, would be steaming, probably, less than twelve knots per hour; consequently, the fast scout, which has been under full steam since sighting the smoke of a large fleet, can easily escape from any pursuing cruisers. Upon being chased, the scout should, if possible, lay a course similar to the apparent course of the enemy's main fleet; so that, when the chase is abandoned, the fleet may again be sighted and more information despatched to the shore station. By keeping a long distance in advance or inshore of a hostile fleet—always, if possible, keeping it in sight, however—a scouting vessel, by despatching pigeons, may be able to keep the shore stations informed of the fleet's movements until it is actually sighted from the land. If one scout should lose sight of the hostile fleet, another would probably pick it up later, and pigeons would carry the news to the shore; thus all the forts and all the ships along the coast could be informed of its approach, and of its general course, speed, and strength.

For the purpose of illustrating the usefulness of the messenger-pigeon service, let us assume: (1) that hostilities exist between the United States and a first-rate naval power of Europe; (2) that the United States has an efficient messenger-pigeon service; (3) that her fast cruisers and the fast steamers of the naval reserve are stationed as scouts along the coast from Cape Sable, Nova Scotia, to Galveston; (4) that the scouts have orders to cruise as far as one hundred miles from the coast and to destroy the enemy's commerce, but if the enemy's fleet is sighted the scouts are to keep in touch with it as long as possible and despatch pigeons with information of its movements, speed, and strength; (5) that the scouts are not to engage the enemy's cruisers sent in pursuit, except as a last resort when hard pressed; (6) that the

Columbia is ordered to scout from Cape Sable, Nova Scotia, to Browns Bank, the St. Paul from Browns Bank to Georges Shoal, the Raleigh from Georges Shoal to New South Shoal lightship, and the Cincinnati from New South Shoal lightship to Montauk Point; (7) that these vessels are supplied with pigeons from all stations on the New England coast and from the New York station; (8) that the battle-ships and armored cruisers are organized in two fleets—the Northern Fleet being stationed in the vicinity of Long Island Sound or New York, and the Southern Fleet at the entrance of Chesapeake Bay; (9) that coast-defense vessels and torpedo-boats are stationed at ports along the coast—three monitors, one ram, and four torpedo-boats at Newport for the protection of the entrance to Long Island Sound, and three monitors and two torpedo-boats at Boston. On June 15th, at 6 P. M., the following pigeon message is received at the Bar Harbor station:

U. S. S. COLUMBIA,
At sea, Lat. 42° 55′ N., Long. 65° 40′ W. (31 S. S.W. Cape Sable),
2 P. M., June 15, 1896.

TO THE SECRETARY OF THE NAVY:

Have just sighted smoke of a large number of vessels to N'd and E'd of Cape Sable, apparently standing to S'd and W'd. I will try to ascertain nature and course of the vessels.

COMMANDING OFFICER.

Upon the receipt of this message, orders are telegraphed to the Northern and Southern fleets to be ready to sail at a moment's notice, and the message is telegraphed to all naval and military stations on the New England coast.

On June 15th, at 7.30 P. M., two pigeons arrive at the Bar Harbor station, each with the following message:

U. S. S. COLUMBIA,
At sea, Lat. 43° 03′ N., Long. 65° 31′ W.,
3.15 P. M., June 15, 1896.

TO THE SECRETARY OF THE NAVY:

Have just sighted a large fleet—probably twenty vessels—to N'd and E'd of Cape Sable, standing about S. W. by W. (mag.) to S'd of Georges Shoal, at rate of about nine or ten knots. Will try to keep in touch of fleet until dark, if not chased, and will then try to lay a course parallel to that taken by fleet.

COMMANDING OFFICER.

Upon the receipt of this message, the Northern fleet is ordered to take station off Newport, and the Southern fleet is ordered to proceed with all speed to New York. All naval and military stations on the northern coast are informed of the approach of a large fleet.

On June 16th, at 9 A. M. and 9.35 A. M., pigeons arrive at the Chatham, Mass., station, each with the following message:

U. S. S. COLUMBIA,
At sea, Lat. 41° 21′ N., Long. 67° 14′ W.,
5 A. M., June 16, 1896.

TO THE SECRETARY OF THE NAVY:

Lost sight of enemy's fleet yesterday at 5:30 P. M., when we were in Lat. 42° 37′ N., Long. 66° 17′ W., having been chased by three cruisers until after dark. Fleet was still steering about S. W. by W. (mag.), to S'd of Georges Shoal, and had been on that course for about three hours. Made out mastheads of eighteen vessels. Have not sighted the fleet this morning, but I hope to pick up smoke very soon.

COMMANDING OFFICER.

The Northern fleet is kept in readiness to sail at a moment's notice, in order to intercept the enemy's fleet if it should head for Boston.

On June 16th, at 12.45 P. M. and at 1.20 P. M., pigeons arrive at the Chatham, Mass., station, each with the following message:

U. S. S. RALEIGH,
At sea, Lat. 41° 02′ N., Long. 67° 51′ W.,
10 A. M., June 16, 1896.

TO THE SECRETARY OF THE NAVY:

Have sighted a large amount of smoke bearing about S. E. by E. (mag.) It is probably smoke of a large number of vessels in company standing to the W'd. I will try to learn something more definite.

COMMANDING OFFICER.

and at 2.25 P. M. the following message is received at the same station:

U. S. S. RALEIGH,
At sea, Lat. 40° 52′ N., Long. 67° 50′ W.,
11.30 A. M., June 16, 1896.

TO THE SECRETARY OF THE NAVY:

Have just sighted a large fleet—probably fifteen or twenty vessels—on bearing E. by S. (mag.). Fleet is standing about West (mag.) to S'd of New South Shoal Lt. Sh., at a speed of eight or nine knots. Two vessels have just been detached from fleet and evidently intend to chase me. I am standing for New South Shoal Light Ship.

COMMANDING OFFICER.

By this message it is seen that the enemy was standing too far to the S'd for an attack on Boston, and was evidently bound for Newport or New York. Consequently, a despatch vessel is sent from New York to intercept the Southern fleet and give orders to the commander-in-chief to take station off Montauk Point, as soon as possible, in order to intercept the enemy, to station a despatch vessel within signal distance of the Montauk Point signal station for the purpose of receiving orders or information from the commander-in-chief of the Northern fleet, and to be ready to move with all speed to the support of the Northern fleet.

At 5.30 P. M. and 5.45 P. M., June 16th, pigeons arrive at the Chatham station, each with the following message:

U. S. S. COLUMBIA,
At sea, Lat. 40° 31′ N., Long. 68° 17′ W.,
3 P. M., June 16, 1896.

TO THE SECRETARY OF THE NAVY:

Have again sighted smoke and mastheads of a fleet bearing E. N. E. ½ E. (mag.), and standing about W. ½ S. (mag.), to S'd of New South Shoal. Speed eight to nine knots. Fleet must contain fifteen or twenty fighting vessels, and has steered the same general course since first sighted by us off Cape Sable yesterday at 2 P. M.

COMMANDING OFFICER.

At 5.20 P. M. the following message is received at the same station:

U. S. S. RALEIGH,
At sea, Lat. 40° 38′ N., Long. 68° 55′ W.,
3.15 P. M , June 16, 1896.

TO THE SECRETARY OF THE NAVY:

We have lost sight of the enemy's cruisers after having been chased for three and one-half hours, and we will now attempt to find enemy's fleet before dark. My last message was sent at 11.30 A. M. to-day, and stated that a large fleet was sighted bearing E. by S. (mag.), when we were in Lat. 40° 54′ N., Long. 67° 50′ W., and that it was standing on a course about West (mag.) to the S'd of New South Shoal, at a speed of eight or nine knots.

COMMANDING OFFICER.

and at 7.10 P. M. and 7.30 P. M. the following message in duplicate is received at the same station:

U. S. S. COLUMBIA,
At sea, Lat. 40° 35′ N., Long. 68° 34′ W.,
4.40 P. M., June 16, 1896.

TO THE SECRETARY OF THE NAVY:

After sending message at 3.00 P. M. to-day, I steamed ahead to avoid enemy's cruisers and lost sight of fleet; but later I slowed engines, and fleet has just been sighted from aloft on bearing E. ½ N. (mag.) Fleet is still steering about West (mag.) to S'd of New South Shoal Lt. Sh., and making about eight or nine knots. Fleet is large, and has kept same general course since passing Cape Sable.

COMMANDING OFFICER.

and at 7.30 P. M. the following message is received at Chatham:

U. S. S. RALEIGH,
At sea, Lat. 40° 30′ N., Long. 68° 50′ W.,
5.40 P. M., June 16, 1896.

TO THE SECRETARY OF THE NAVY:

Have again picked up enemy's fleet on bearing E. S. E. (mag.), and it is steering about West (mag.), to the S'd of New South Shoal Lt. Sh., making eight or nine knots. Fleet seems to have between fifteen and twenty ships, and has been making course West (mag.) since I sighted them at 11.30 A. M. to-day. I will keep in touch with fleet until dark if permitted to do so by the cruisers. The evident intention is to make an attack on Newport or Long Island Sound at daylight to-morrow.

COMMANDING OFFICER.

The above message is telegraphed to all points on the coast and full preparations are made to resist the attack. The Northern fleet is informed, by despatch vessels, of the enemy's movements; and the Montauk Point signal station is telegraphed to signal the information to the Southern fleet upon its arrival.

At 6.35 A. M., June 17, two pigeons arrive at the Newport station, each with the following message:

U. S. S. CINCINNATI,
At sea, Lat. 40° 24′ N., Long. 70° 50′ W.,
5.00 A. M., June 17, 1896.

TO COMMANDANT NEWPORT NAVAL STATION:

Have just (daylight) sighted a large fleet on bearing S. W. by S. (mag.). Fleet is standing in for Newport. Cannot make out number of vessels. I will slowly approach the fleet to learn its strength, and I will run for Newport when chased.

COMMANDING OFFICER.

The Northern fleet gets under way at daylight from anchorage near Block Island, and at 7.45 A. M., when 8′ S. E. by E. of Block Island, it is signaled by a despatch boat and given the above message from the Cincinnati. The message is telegraphed to Montauk Point for the Southern fleet, with orders to cruise off the east end of Long Island, but within easy communication of the Montauk Point signal station.

At about 7 A. M., June 17th, messages, in duplicate, are received at the Chatham and Newport stations from the Columbia and Raleigh, stating that the enemy's fleet had passed about 20 miles to the S'd of New South Shoal lightship, and had laid a course for Newport between 2 and 3 A. M., steaming about 10 knots; and that at daylight the fleet had been sighted in lat. 40°

12′ N., long. 70° 59′ W., heading for Newport, and that Columbia and Raleigh were making for Newport.

At 7.10 A. M., June 17th, three pigeons arrive at the Newport station, each with the following message:

U. S. S. CINCINNATI,
At sea, Lat. 40° 22′ N., Long. 70° 47′ W.,
5.40 A. M., June 17, 1896.

TO COMMANDANT NEWPORT NAVAL STATION:

Enemy's fleet bears S. ½ W. (mag.), distant about seven miles, heading for Newport at speed of about twelve knots. The fleet consists of twenty-three vessels, and, as well as I can make out, are as follows: six battle-ships, five armored cruisers, eight cruisers, and four large torpedo-boats. The present formation is double column, battle-ships leading, with torpedo-boats between main columns. I am making for Newport under full speed, being chased by two cruisers. I have not yet sighted our fleet, but have just sighted a vessel to E'd, off starboard quarter, and it is probably Raleigh making for Newport, as enemy has just sent a cruiser after her. Enemy has just sent torpedo cruisers ahead as scouts.

COMMANDING OFFICER.

This message is telegraphed to the Montauk Point signal station for the Southern fleet, and is immediately sent to the Northern fleet by a twenty-knot despatch vessel; and the fleet is signaled at 8.30 A. M., 15 miles S. E. ½ E. (mag.) of Block Island, just after it has made out the Cincinnati and Raleigh, and has sighted a large amount of smoke to the S'd.

At 7.40 A. M. pigeons arrive from the Raleigh with messages of same general purport as the message from the Cincinnati.

At 8.20 A. M., June 17th, three pigeons arrive at the Newport station, each with the following message from the flagship of the Northern fleet:

U. S. FLAGSHIP KEARSARGE,
8′ S. E. by E. (mag.) of Block Island,
7.50 A. M., June 17, 1896.

TO THE COMMANDANT NEWPORT NAVAL STATION:

Have just received Cincinnati's message dated five o'clock this morning. Will endeavor to engage the enemy about 26 miles S. by E. (mag.) of Pt. Judith. Send the three monitors, the ram, and torpedo-boats with all speed to join me at that point. Sea smooth—very favorable for monitors and torpedo-boats. Telegraph Montauk Point Signal Station to signal Southern Fleet to join me with all speed at a point 26′ S. by E. (mag.) of Pt. Judith; also send a despatch vessel to communicate with Southern Fleet off Montauk Pt. Have just sighted two vessels. One is probably Cincinnati. She will remain with the Flag.

COMMANDER-IN-CHIEF.

At 10.35 A. M., June 17th, two pigeons arrive at the Newport station, each with the following message:

U. S. FLAGSHIP KEARSARGE,
24′ S. by E. ¼ E. (mag.) of Pt. Judith,
9.45 A. M., June 17, 1896.

TO THE COMMANDANT NEWPORT NAVAL STATION:

Have just engaged enemy at long range. Torpedo-boats are just arriving and monitors are in sight. Enemy's fleet is composed of seven battle-ships, six armored cruisers, six cruisers, and four torpedo-boats. Telegraph Southern Fleet at Montauk Pt. Signal Station to join me with all speed at this point, if you have not already done so. Telegraph Boston to send monitors with all speed to take station to the E'd of Phelps Bank, in order to cut off retreat of enemy.

COMMANDER-IN-CHIEF.

At 1.35 P. M., June 17th, the following message, in duplicate, is received at Newport:

U. S. FLAGSHIP KEARSARGE,
26′ S. S. E. (mag.) of Point Judith,
12.50 P. M., June 17, 1896.

TO THE COMMANDANT NEWPORT NAVAL STATION:

Have closed to 1600 yards, both sides suffering severely. Enemy's losses are: two cruisers and one torpedo-boat sunk, two armored cruisers set afire and disabled, and two battle-ships partially disabled—unable to fire barbette guns. Have just ordered Cincinnati, San Francisco, and Montgomery to attempt to make the Sound. They are disabled and leaking badly, so send tugs to meet them between this point and the Sound, and tow them to New York with all speed. Telegraph New York Navy Yard to have docks ready to receive disabled cruisers. Monitors are doing effective work. Southern Fleet has been sighted. Brooklyn has signaled that she is seriously damaged and unmanageable. Have signaled Detroit to tow Brooklyn beyond the line of fire and to try to make Newport. Send some vessels to her assistance. Take her to New York if possible, and only beach her as the last resort. Have lost one torpedo-boat.

COMMANDER-IN-CHIEF.

In the event of hostilities, many more pigeon messages than those given in the above illustration would be sent, in order to insure the receipt of the important information. The latest message should always repeat in a general way the information contained in the messages that preceded it. If even a few messages would be received in case of actual warfare, the messenger-pigeon service would prove most valuable to the navy. Service of similar value to that given by the pigeons in the above illustration would probably be given in the event of a hostile fleet leaving Havana for an attack on our fleet off Key West, leaving

Esquimault for a raid on Puget Sound ports, or appearing on the Great Lakes.

A messenger-pigeon service could be made very useful to the army by locating stations at important military posts. The most important would be near the Canadian and Mexican frontiers, so that an invading army could keep in communication with its base. Pigeons would be very useful messengers during Indian campaigns, especially when the campaign is in a mountainous country. In all such campaigns the pigeons would be efficient, because they are swift in flight and are not in danger of capture by the enemy. They would thus replace the courier, who is in constant danger of capture, and whose speed over mountain trails is necessarily very slow.

The expense of establishing a messenger-pigeon service for naval purposes would be very small in proportion to its usefulness to the government. It must be remembered, however, that such a service cannot be improvised.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

BLOCKADE IN RELATION TO NAVAL STRATEGY.

By Captain A. T. Mahan, U. S. Navy.

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The Council of the Royal United Service Institution have done me the honor to ask a paper upon the following thesis: "The naval strategy of the past has been dependent upon power to maintain close blockade of hostile ports. Can such blockade be maintained under present conditions of steam, steel, and torpedo-boats? If not, what modifications are demanded by the circumstances, largely varied, from past wars?"

That this is a question involved in great difficulty, if not obscurity, will be readily admitted by all who have given thought to the conditions, or have had experience of them. No reply can be more than tentative until we have the experience of actual war, or until there is made a more exhaustive attempt, than I think has yet been done, to reproduce all the difficulties—not on one side only, but on both—as well as *all* the careful measures to insure success that would be taken by a man under the actual weight of responsibility. Experiments upon war, in time of peace, have little advantage over a game, unless the effects of danger and of doubt, in inducing caution and precaution, can be represented to an extent that they now rarely are.

Under these circumstances my reply must reduce itself largely to an attempt to compare the conditions of the past with those of the present, in order, not so much to decide myself, as to facilitate a conclusion, whether the change, superficially so great, is really one of kind, or of degree only.

It is allowed on all hands, as an historical fact, that such blockades were instituted and maintained with great rigor and efficacy, though always subject to the chance of successful evasions, during long periods of the French Revolutionary wars. Under former conditions, often both severe and complicated, the thing was done. The question now proposed is: " Can the same, or an equivalent, system be maintained, under the changed conditions of the present day? "

The fact that the question raised depends upon conditions essentially transient in character—conditions which are of the present, not of the past, nor at all certainly of the future; conditions characteristic of the vessels and of the weapons with which the strife is to be fought, rather than of the unknown regions which may be the theater of war—constitutes a fair presumption that the problem itself is in its nature more tactical than strategic —in the strict sense of the latter word.

It is evident, also, that we must not too lightly assume the methods of former days, however admirably they may have been adapted to the ends then in view, as mere precedents, to be followed unquestioningly in our modern practice. We can only safely reason upon the experiences of the past when we have penetrated to, and laid firm hold upon, the principle, or principles, which received recognition and interpretation in our predecessors' methods. When the latter have stood the searching criticism of experience and analysis, we can confidently assert that they were a valid application, under the conditions of one age, of principles that are probably true at all times, and which we may hope to detect by patient study. But when we have correctly stated the principles, it by no means necessarily follows that the application of them will be the same, or superficially even much like those of previous generations.

There is another caution which I think may wisely be observed, namely, not to assume too easily that our forefathers hit upon methods absolutely certain of success in practice—not liable at times to failure. There are few, if any, characteristics of the utterances which I from time to time hear, or read, on the subject of actual warfare, which impress me more strongly than the constantly recurring tendency to reject any solution of a problem which does not wholly eliminate the element of doubt, of uncertainty, or risk. Instead of frankly recognizing that almost all warlike undertakings present at best but a choice of difficulties—that absolute certainty is unattainable—that the "art" consists, not in stacking the cards, but, as Napoleon phrased it, in getting the most of the chances on your side—that some risk, not merely of death but of failure, must be undergone—instead of this, people wish so to arrange their programme as to have a perfectly sure thing of it; and when some critic points out, as can so easily be done, that this may happen or that may happen, and it is seen undeniably that it may, then the plan stands condemned. "War," said Napoleon again, "cannot be made without running risks, and it is because my admirals have found out that it can, everything attempted by them has failed." Even had we not that high authority, the experience of the blockade system of the past, which forms the basis of the question proposed for treatment, would show that, however sound in principle was the practice of those days, it was by no means infallible; that it ran great risk of failure from circumstances, sometimes anticipated, sometimes unforeseen; and that such risks, constantly incurred, and indeed inseparable from the conditions, did from time to time cause failure and partial disaster. Most of us will recall Nelson's exaggerated expression, "Nothing ever kept the French fleet in Toulon or Brest when they had a mind to come out"; but this exercised no deterrent effect upon his resolve "never to lose sight of the Toulon fleet." He and the men of those days, whether they analyzed their convictions or not, were of a temper which did not yield under partial defeat. They stuck to a plan which in its accuracy seems almost intuitive, so wanting is it of technical expression, or reasoned statement, in their writings; and, as the principle on which it rested was perfectly sound, and the practice based upon the principle substantially the best available to them, they realized the success which in the great majority of cases will reward a right line of action, consistently followed through the ups and downs of good and evil fortune. As the Scriptures have it, "He that endureth to the end shall be saved."

It behoves us, therefore, to consider, first, what was the principle which found expression in the close blockades of the last century and early years of the present; and here I may remark, in passing, that the very word "close" to a certain extent begs the question, and assumes a power which did not actually always exist for the blockading fleet. Nelson's statement, above quoted, by no means stands alone. "Here we are," wrote Collingwood (I quote from memory), when in charge of the Rochefort blockade, "lying to in a heavy gale, ninety miles off shore. I cannot with certainty prevent the enemy slipping out before I return, yet I should be intensely mortified if he succeeded. *The only thing to deter him is the fear that he may fall into our midst.*" These last words are worth remembering, as indicating the doubt that the enemy too must have—that he, too, must run risks—and that, if the fear here suggested were realized, disaster would fall upon his schemes. Many a happy chance has slipped through the fingers of this or that warrior because he did not know the hazards to which his opponent was willingly, or necessarily, exposing himself; and excessive pre-occupation of the mind with one's own risks or difficulties is often the cause that blinds men to such chances. I believe that failure to achieve great results is more often due to anxiety about one's own dangers than to over-confidence and rashness. There is a time for prudence, but there is also a time for daring. "It is better to be alarmed now, as I am," wrote Torrington, "than next summer when the enemy is out." Over-caution in campaign may possibly prevent immediate disaster, but it is equally apt to cause ultimate ruin by failure to utilize opportunity. Nelson's biting comment reaches many more men than the admiral at whom it was first launched: "He is perfectly satisfied that each month passes without any losses on our side."

The two great historical instances of blockades, so called, upon a really extensive scale, and sustained with steady resolve through considerable periods of time, are the blockades of the French military ports by British fleets during the Seven Years' War and the Napoleonic era, and the blockade of the coast of the Southern Confederacy by the United States Navy during the Civil War, 1861-65. The latter, however, was a purely strategic operation, which may be accurately described as a steady and strangling pressure upon the enemy's lines of communication, with the result of producing exhaustion through the failure of necessary resources. It resembled, even in method, the Continental blockades of Napoleon's decrees and of the British Orders in Council; and of their spirit, except that they disregarded existing international law, it was a precise reproduction, in the suppression of trade through an extensive coast line. Owing, however, to the fact that there was practically no hostile navy to be dreaded, no tactical precautions had to be observed by the blockading forces. These were, in consequence, loosely distributed over an immense line, without any thought of mutual support, or of danger from an enemy. Never did the cordon system, so sweepingly, yet justly, condemned by sound military writers, when adopted as a defensive plan against a valid enemy, receive a more complete illustration; yet, under the conditions of the time, it was admirably calculated for the particular emergency. The United States vessels had not to think of possible injury to their own coast, or to their distant interests, by the escape of the enemy's ships, except in the depredation upon sea-borne commerce by scattered cruisers. The escape of the latter, in isolated cases, through the blockading line could not be prevented; while to protect the trade threatened by their evasion would have required the detachment of so many vessels as to impair seriously the attainment of the far more important military object of the blockade—a fact worthy of most serious consideration in connection with the present subject; for it justifies the remark, parenthetically, that the vast increase of force necessary to repress damage by vessels that have escaped, over that required to prevent their escape in numbers sufficient to constitute a serious danger, emphasizes forcibly the imperative need of intercepting such escape, if it can be done. It will probably, therefore, be admitted by all, that the blockade of the Southern coast was a purely strategic operation, involving little or no practical difficulty regarding the manner of distributing the several detachments upon their respective, and often petty, scenes of operations.

The case was radically different with the British Navy in the periods 1756-1763 and 1793-1814. Whatever the strategic plan, the consideration of which we will for the moment postpone, the problem which its adoption presented to the British admirals was one essentially tactical, viz., how to dispose their ships before the hostile ports, and how to maintain them there, in such wise as to prevent the unmolested escape of one or more divisions of vessels, which, if once away, might do incalculable harm before traced to the unknown goal for which they were destined. That the usual tactical aim of the French was the exact converse of this is, I believe, generally recognized. Their object was to evade the force stationed before the port, to shun battle, in order to effect a certain injury to the enemy's possessions; or, in rarer cases, to support large combined movements of the land and sea forces in regions more or less remote. Under such conditions, the duty of the watching fleet, as long as it lasted, was excessively onerous. Not only did it entail a state of uncertainty and prolonged anxiety, indecisive of tangible results, but by far the greater strain fell upon the outside fleet, which was in the position of the defendant and underwent most arduous exposure. For all these reasons, but particularly because it was necessary to end suspense and to bring matters to an issue, the primary hope of the British admirals was not to shut the enemy up in his ports, but to compel him to battle when he came out, or as soon thereafter as practicable. The blockade therefore was to be "close," so far as that word was at all applicable, for this purpose only. It is well known that Nelson, with his clear perception of facts in their mutual relations, emphatically rejected the term "blockade" as applicable to his own operations before Toulon. "On the contrary," said he, "every opportunity has been offered them to put to sea, for it is there we hope to realize the hopes and expectations of our country"; but at the same time he, with equal emphasis, and free use of superlatives, charges his frigate captains, "It is of the utmost importance that the enemy's squadron in Toulon should be most strictly watched, and that I should be made acquainted with their sailing and route with all dispatch."

Accepting this as the real expression of the British aim, which upon the great authority of Nelson we well may, let us now try to weigh the advantages and disadvantages, as compared with the conditions of to-day, under which the British admirals then worked in conducting a plan, the success of which I presume is now generally accepted. For of one thing I think we may be reasonably certain, that the strategic danger, and the strategic aim, of a navy which seeks to close-watch hostile ports, are the same to-day as formerly. Whatever the number of ships needed to watch those in an enemy's port, they are fewer by far than those that will be required to protect the scattered interests imperiled by an enemy's escape. Whatever the difficulty of compelling the enemy to fight near the port, it is less than that of finding him and bringing him to action when he has got far away. Whatever the force within, it is less than it will be when joined to that which may, at or near the same time, escape from another port. Whatever the tactical difficulties involved, the strategic necessities compel a diligent study of how to meet them.

The greatest change in the conditions, I apprehend, is the facility now enjoyed by the inside belligerent of moving at any time, and in any direction; to which, and incident thereto, is to be added the fact that the indications of an intention to move are less open to observation than formerly. Then, with the wind in certain directions, the outside ships could feel perfectly sure that the opponent could not come out; and when a successful sortie had been made, but the escaping division been seen by a look-out frigate, the course steered with reference to the wind prevailing might (or might not) give some clue to the destination. It would be pedantry to cite from the numerous proofs of these statements in the correspondence of the day. The same is not the case now—certainly not in any degree comparable to what then obtained. Unless I mistake, the general opinion of those who have had experience is, that it is impossible to prevent the escape of the inside ships. Not having the experience, I feel very great diffidence in expressing even a partial dissent; but when I observe that the conviction of the difficulty of detecting an escaping enemy does not seem to qualify perceptibly the assurance that the low-lying torpedo-boat will easily find its prey under similar circumstances, it appears to me possible that we have here again an instance of the tendency to see all the difficulties on our own side and the advantages on the other. Still, it does remain true that, unless you can compel the enemy to come out at once, or at least very soon, the choice of time and conditions remains with him. All that can in compensation be said is, that the outside party has the same facilities for judging what is practicable at any moment, as the inside; and that the dispositions of each day and night must be made to correspond to the conditions of weather and other circumstances. A night favorable to the operations of the torpedo-boat will not justify the same arrangements as one where it can with difficulty discover its object, or fire with precision.

The question, therefore, presents various phases, but is it not after all essentially one of look-out? of watching a line more or less long, which the enemy may break through at any point, or at least at several points? Whatever the length of the line, the situation in so far reproduces the essential characteristics of one very familiar in warfare, when one party stands on guard over a long line. This has in the past been variously met. The cordon system, so well known from the liberality with which it has for some generations been condemned, sprang with all its faults directly from the necessity of guarding in some way a long line. It is true, however, and will no doubt be urged in reply, that there is a most important difference in the fact that, the line being once broken through, the great mobility of a naval force enables it to be off and away for its destination, and possibly to disappear from sight and knowledge, without permitting that gathering of the defendant's masses which may be necessary, before pursuit can be adventured. Here, however, very much will depend upon the length of the line through which evasion may be attempted. In a port with but one entrance this may be greatly contracted, according to the dependence the outside party feels in his own protective measures against surprise, and especially against torpedoes. Such a port would resemble a river, or a mountain chain, with but one practicable passage. In a port with two or more practicable exits the difficulty is increased in proportion to the distance of these apart, and the other hydrographic conditions. Two entrances may do no more than dictate a central position for the outsider's force, or it may compel him to double it. The weather, again, will modify the length of the outside blockading line—the area, that is, of the circle upon whose circumference the battle-ships will lie or move. The inner line, the sentries, must always be close in.

It is unnecessary to insist that the belligerent who proposes to take position off the enemy's ports must possess decisive superiority. This is universally admitted. The outsider has the more difficult task; he is on the defensive; he undergoes more wear and tear. He also, as has been intimated, ought to incur as little delay as possible in concentrating a pursuing body, at the least equal to the party escaping. The only adequate provision for these conditions is greater material force. Moreover, the ships with clean bottoms should always be as numerous—at the very least—as the enemy's ships of the same class within. If track of an evading division is not lost, a very consequential factor in pursuit is likely to be the ship first to give out or to slow down. This is a contingency that cannot be dismissed as improbable. It is just such chances as are continually happening—*l'imprévu qui arrive.* Who, with the experience of summer manœuvres, will say that in a division of six battle-ships and attendant cruisers, pressed at high speed to shake off pursuit and proceed on a mission—or, on the other hand, to pursue such a force—the risk of a hot journal or some breakdown in machinery need not be taken seriously into account?

Let us, as an example, assume such a division to have run out, and that by clever stratagem or otherwise it has got twenty miles' start—a long start in a stern chase—before the outsiders get on the track. Two of the heavy (or fast) cruisers—look-outs—that should ply in couples between the sentries and the main body, have not lost their touch and are following. It is impossible they should be attacked, for their main body is following; therefore they cannot be shaken off. Assuming equality of speed and luck—and equality at the start must be assumed, unless we are to have problems too hopelessly complicated for discussion—the chance is equal in which squadron a laggard will turn up; but, if the chance happen to the pursued, it is much more serious than it would be to the pursuer, for he must abandon the ship or fight—which, again, means abandon his mission. The pursuer, on the other hand, simply leaves his ship behind and continues pursuit. He certainly would not abandon it, for what has happened to him may next happen to the enemy. Even if it be a battle-ship he has lost, and he therefore is by one inferior, he would not be justified in letting go his grip, and with it the chances which the chapter of accidents may next offer.

It may, however, be urged that this escaping by a whole division is not what will be attempted, but that the inside party will send his ships out separately—on the same or on different nights—with orders to assemble at a given rendezvous. But will he? I at least am not so sure; for if on the one hand there is thus multiplied by six the chance of evasion for each ship, there is also multiplied by six the chance that one will fall in with the whole of the outside squadron. A single battle-ship of the present day is too valuable—in immediate money's worth, in importance to the general operations, and in the length of time required to replace her—to be so daringly, not to say recklessly, risked. The mere capture of one such ship would be no small night's work, equalling, as she would, in tonnage and in intrinsic importance to the operation before her, the five ships taken by Rodney on the 12th of April. I am not disposed to undervalue the advantage of the insider, in that he has the initiative—the advantage possessed by one who has the choice of time, whose different parties move on a preconcerted plan, for a single, simple object (getting away), over one who cannot distinguish just what is happening, which is the position of the outsider. On the other hand I feel that, in considering the possibility of effectively watching an enemy's port, which is the *rôle* of the outsider, one is likely, from his very point of view, to be over-impressed with its difficulties; and I am inclined to think that, if the problem posed were how best to win through the toils of a much superior and skilfully disposed outside force, imagination would succeed in making a similar vivid picture of the risks of running out—of the things that might happen, and the disastrous consequences that might thereupon ensue. Men will not in war undertake with a light heart, adventures which in summer manœuvres entail no more grievous burden of care than a boy's game of hide and seek. Valuable as are the lessons of mimic warfare, there cannot in it be adequately reproduced the element arising from the sense of imminent danger.

Moreover, it should be remembered that, if the blockade has continued for some time, the escaping ships, despite the advantages otherwise possessed by them (clean bottoms, full coal, etc.) will have to do with vessels that have had nightly experience of embarrassments, which they themselves will be undergoing for the first time; a condition precisely analogous to that lamented by Villeneuve when he wrote, "They have not been exercised in storms"; or, as Nelson wrote of the same occasion, "These gentlemen are not used to the hurricanes, which we have braved for twenty-one months without losing mast or yard." Is any one disposed to reck lightly of the moral effect—that most potent spell—or of the trained dexterity, acquired by the mere habit of doing things in the dark and under difficulties? Evasions, if undertaken at all, will not be on moonlight nights and smooth seas, but under conditions that will, to say the least, favor evasion. The same conditions will also, beyond all doubt in my mind, as far as their special influence extends, favor the familiar outsider rather than the unfamiliar insider.

It is clear that the difficulties of the outsider are multiplied manifold, if once the evading party is wholly lost to sight; hence it follows that the most strenuous efforts must be made not to let him escape without fighting. If I may, without affectation of pedantry, translate this proposition into technical language, it would read that the strategic necessities of the war demand that the area to be occupied by the outsider's fleet (*i. e.*, before the enemy's ports) be circumscribed to the tract consistent with due precaution against attack, and that there be concentrated upon it such a force as would render escape without fighting impossible. The retort doubtless will be that no one denies this, but that the very question before us is how to prevent the escape. Can any force, however numerous, be so disposed as to prevent a sortie being seen? If seen, can the news of the fact, and the necessary information as to direction taken, and the enemy's force, be so transmitted to the main body of the fleet as to give a probability of the latter intercepting the movement? If once seen, can touch of the enemy be kept? Can any change of direction he may make be also distinctly reported? In short, if such a movement is made and discovered, and touch with it is once gained, can such touch be maintained until daylight, or clear weather, enable eyesight to resume its functions? After that the question becomes one of alternative speed and possible accidents.

This series of questions, I apprehend, really states the problem under consideration. The question of relative speeds is not involved, it only comes into play if the fleets see each other, and one is trying to force action; it is, moreover, perfectly simple, as well as outside our problem. Neither is the relative fighting force primarily involved—the superiority of the outsider in this must be assumed—otherwise his attempt to play his part at all is hopeless. The question is simply one of touch, gained and maintained; of immediate and accurate information, and consequently of correct direction given to the party wishing battle. For this, numbers are primarily necessary. The scouting force of the fleet—its eyes, its cavalry—must be so multiplied, organized, and drilled that it can at one and the same time keep track of an enemy and go back and forth to its own main body. This being effectively done, the superiority of the latter comes into play.

Now, there is in this nothing original—nothing whatsoever. It is a mere re-echo of Nelson's cry—not only before the Nile, but at other times—" More frigates!" As a contribution to the question I was asked to treat, the answer I suggest amounts to no more than this, that it eliminates, in my opinion, all subsidiary and related subjects, and reduces the problem to the one simple, though great, difficulty in which I conceive it to consist. The maintenance of a close and sustained watch over a hostile port, of which we have two great types in St. Vincent and Cornwallis off Brest, and Nelson, under very different conditions and methods, off Toulon, involves many intricate problems. There are the questions of the aggregate purely fighting force to be kept up, its movements and position and all that pertains to its instant readiness, questions of supply, of reliefs, of repair, of reserve, difficulties consequent upon weather; but all these are separable, in thought at least, from the organization of what I have called the cavalry of the fleet. The admirals of former days found it hard to exaggerate their sense of its importance, but the greater facility of movement accorded by steam certainly does make evasion easier than of old; consequently the look-out force must be more numerous, more swift, more systematically organized and drilled.

To make more than a general suggestion, to propose more than a general solution, to go on to propose classes of vessels, methods of operation, and so forth, would, it seems to me, transgress the proper sphere of an officer foreign to the service he is addressing, and for various reasons. Let me, however, recur to one remark already made. The answer I offer may be wholly unsatisfactory, may be a mere lame and impotent conclusion. I of course think that, carefully worked out, first, as to the tactical disposition most conducive to the end in view, gaining and keeping touch, and thence deducing the classes and relative numbers of the vessels needed for the various lines of the blockade, from the outmost to the innermost, a very adequate plan can be evolved. It would have a general resemblance, doubtless, to the sentries, piquets, and supports, that lie between the main body of an army and the enemy; or, to quote a naval historical instance, to the method of the Brest blockade described by St. Vincent in his letters. But, as I have already remarked, unless the idea is futile—barren—its inadequacy demonstrated by experience or logic, it is not a sufficient reply to show that it may, by this chance or that chance, by this mistake or that mistake, incur failure. If a perfectly sure thing is required, I certainly have none to propose or advocate. Supposing a plan based upon the idea I suggest, or upon any other, the fair question to be asked by one weighing it, is not, "Does this make it impossible for the enemy to escape?" but, "Does this impose upon him such risks as to give a considerable chance of either stopping or crippling him, if he attempt it?" And not only is this chance in your favor to be considered as to the immediate locality, but also as to its deterrent effect upon the enemy; and, consequently, the impediments raised by it in the way of any great combination, dependent upon the evasion taking place at a particular moment. As I have repeatedly argued in my book upon the Napoleonic wars, it was not the certainty of stopping a particular evasion, but the high probability of frustrating a great combination, that made the distinguishing merit of St. Vincent's system.

The ease of movements both in time and direction, conferred by steam, again intervenes here to exaggerate, in my judgment, both the supposed facility of combinations effected from separated ports, and the assumed consequent danger incurred from them. Sight is lost of qualifying conditions. Men's imaginations, kept in constant activity by the scientific advances and inventions of the day, have developed abnormal agility, and mental pictures are drawn in which fleets get about as though by magic. The movements of modern fleets are in fact extremely hampered, and their scope restricted, by the very elements to which they owe much of their power. Their coal, ammunition, water, and supplies are immensely less, measured in duration of time, than the corresponding factors essential to the efficiency of the old ship of war. Nor are they thus fettered only by causes internal to themselves, but external conditions deprive an evasion of much of its former menace. Squadrons and divisions cannot disappear as completely, nor for so long, not even comparatively to modern conditions, as they formerly did. With a network of cables under the sea to neutral ports, where abide the consular agents of each nation, the need of renewing coal will make a fortnight a long time for a fleet to disappear from the world's knowledge. A fortnight, you will say, will allow much damage to be done. Doubtless, but not vital damage, if the enemy be decently prepared. It is not to be presumed that a maritime nation will allow its vital interests, home or colonial, to be so exposed that a fortnight's gain of time will prove fatal to any one of them; while, as for lesser interests, or smaller injuries, one does not go to war expecting never to get a shin barked or a limb broken.

I think that the consideration of the difficulty of effecting such vital damage will have a further deterrent effect upon the insider—the weaker party—and conspire with that exerted by the outsider's thorough arrangements, to gain and keep touch, to make him very wary and cautious as to what he attempts. Also of course, if the latter accepts Napoleon's dictum that "War cannot be made without running risks," or, as Jomini more strongly puts it, "After all, one goes to war expecting to take risks," he will not abandon plans of offense because there is difficulty in them, or because disaster may ensue upon failure. The weaker must be the more wary and the more cunning; but he should not despair, and should aim to be also the quicker and the more energetic. The outsider may be stronger before each port than the insider; but the detachment before each hostile port can scarcely be as large as the whole of the enemy's navy. The cruise of Admiral Bruix in 1799 is the conspicuous illustration of the opportunities which chance may offer; though it must be remarked that that chance was obtained, not by a mass formed by detachments combining at sea, but by one already gathered in a single port, from which it issued in mass. The intended subsequent combination with the Spaniards proved in fact a failure; it could not be effected, until after the possible offensive purpose of the cruise had been defeated, by the junction of the British divisions. "What a game had Admiral Bruix to play," said St. Vincent; and Nelson afterwards: "Your lordship knows what Admiral Bruix might have done, had he done his duty." The opinion of two such men, then on the spot, stamps beyond question the possibilities offered to the inside party, by chances inseparable from war. The attempt to close hostile ports against evasion is almost imperative upon a nation dependent upon the sea; yet if done less than efficiently—I do not say "absolutely"—it may quite possibly involve greater danger than leaving the ports unwatched, and simply keeping your own fleet massed and in hand, which was Lord Howe's plan.

In conclusion, I should be inclined to summarize the whole question somewhat in the following manner, which will doubtless involve a certain amount of repetition. Using the term "blockade" loosely, as the nearest single word to comprise any close watch over the entrance to an enemy's port, with a view to impede egress or ingress, such blockades are of a twofold character—

offensive and defensive. The first is directed against both egress and ingress, but more especially against ingress, being meant to prevent the entrance of needed supplies, and being therefore essentially a blow at communications. The second also has a twofold aim, but its chief object is to prevent egress unmolested, because such freedom of issue to an enemy means danger, more or less great, to certain national interests; which, because they lie outside the national boundaries, cannot be protected by ordinary defensive measures, by fortifications and organized land forces. Such a blockade is, therefore, essentially defensive. Resort to it implies the existence of great national *external* interests, which are open to injury, and can in no other way be so cheaply, sufficiently, and certainly defended. If the external exposed interests are many, it is impossible to imagine any means of guarding them equal in efficiency to that of heading off danger at its sources. This is the strategic necessity—the decisive strategic consideration, which dictates the method essential to be adopted. Resort to this method implies, besides the external interests, a naval strength so superior as to permit being before each port watched, in force superior to that of the enemy within. This is a simple question of preparation, which, however arduous it may be to the national resources, presents no intellectual problem difficult to be solved. It is a question principally of money, secondarily of preparation, not only adequate in the aggregate, but adequate in the discretion with which that aggregate is apportioned among the various branches of the fleet, based upon a due recognition of the part which each branch will have to play in a proposed blockade. Such antecedent appointment is as really tactical in character as is the disposition of a given force before a given port.

Further, to assign to a given blockade a fleet of battle-ships, superior in any required degree to the inside enemy, presents no problem perplexing to the intellect. The real problem is to assure a reasonable probability that that fleet can bring the enemy to action, if he attempt to come out. This is a matter of look-out, instituted and sustained, and of means of inter-communication between vessels of the blockading force—whether by signals or by hail. This is the crux of the matter, and it is one so intricate and onerous, subject in execution to so many mishaps, that I do not wonder it should seem insoluble. Without due personal experience, I speak with the utmost diffidence, but I believe that by the employment of extensive means it is possible to attain, not certainty, but that degree of probability which, both in actual result and in its deterrent effect, would largely insure the end in view, the protection, namely, of the external interests of the country. The question involved is the defensive watching of a given front of operations. The system must resemble in general features that of an army similarly engaged. Nearest the enemy the units of force must be small, and their commanders deeply impressed with the sense, not only of the need of quickly gaining and sending information, by whatever means, but also and still more that the safety of their individual commands is as nothing to the performance of the duty assigned. Why, even, should it be thought improbable that a resolute attack upon an issuing force, by the look-out lines, though necessarily inferior, should so embarrass or injure the enemy under the difficulties of night, as to gain time for its own main body to come up—or else might frustrate the movement by the resultant confusion? Certainly it is contemplated, on all hands, that attacks by torpedo-boats from inside will be one of the greatest anxieties of a blockading force; why should it not in a degree concern one trying to run out? In land warfare, inferior force often retards or disquiets movements which it is inadequate to prevent; can no ingenuity figure analogous use of naval force? Many things go to constitute inequality besides physical or material strength—position, opportunity, accident, chance, a happy inspiration. There is nothing in the essential nature of war which makes improbable, under any change of ships or weapons, that there should be repeated the part played by the frigate Penelope, in impeding and ultimately frustrating the escape of the 80-gun ship Guillaume Tell from Malta, in the year 1800. A party whose one aim, for whatsoever reason, is to evade, is sorely hampered in its endeavors to shake off even a much inferior foe. The fear of the delay entailed may prevent it from resorting to measures which, under other circumstances, would soon crush the petty intruder.

In short, to summarize once more in a sentence, the question—the old question and the new alike—is not, "Can any enemy be prevented from coming out?" but, "If he does, can touch with him be gained and preserved?" Steam, in my opinion, has simply widened the question, not changed its nature. I believe that provision can be made which will give a high probability of success, but I do not believe in certainties in war.

DISCUSSION.

THE DISAPPEARING GUN AFLOAT.* (See No. 75.)

CHAS. H. CRAMP, Esq.—From an examination as exhaustive as the limited time would permit, the report on "The Disappearing Gun Afloat" seems to cover all points involved in the particular scheme which formed its subject-matter, and to that extent is perfect.

There can, in my opinion, be no question as to the advantage of the disappearing system in naval gun-mounts, provided mechanical devices can be found to operate it efficiently and reliably within the necessary limitations of weight and space. The system itself is by no means new, having been, as is pointed out, employed by the English in the Temeraire nearly 20 years ago, and by the Russians in the Catharine II, Tchesme, and Sinope ten years ago. The types differ in detail, but not in principle; both being hydraulic and both involving trunnioned guns working on levers; bell-crank in the case of the Temeraire and straight in the Russian ships. King, in his "War Ships and Navies of the World," published about 15 years ago, reports that the performance of the Rendel system in the Temeraire was satisfactory, but he does not describe the conditions of trial. The Russians did not publish the performance of their ships, but so far as I can learn, the Moncrieff system in use in the three battle-ships of the Black Sea fleet has functioned well in smooth water. I have no data as to any performance when the ship was rolling.

This brings me to remark that the principal, and possibly insurmountable, mechanical difficulty in adapting any disappearing system to all-around naval use, irrespective of sea conditions, is that of assuring proper function of the mechanism in all the different planes presented by a ship's motion in a sea-way. Any properly designed and constructed disappearing gun-carriage will operate well when the line of recoil is perpendicular to the plane of a fixed base, as in shore mounts. But I do not know of any device which would insure proper action of the supporting levers and the mechanism controlling them when the gun is fired, say directly forward with the ship at an angle of heel such as to throw a preponderating weight on one lever. It has been suggested that heavy guides in arc form might be fitted to take the sidewise thrust in such cases, but until such a device shall have been worked out and tried no reliable opinion can be formed as to its adequacy.

The scheme which forms the basis of the report contemplates the disappearance of the gun, shield and all, on a line perpendicular to the keel, into a barbette. This would necessarily involve a barbette of

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* Further discussion on the subject-matter of this paper is requested.—ED,

inside diameter equal to the length of the gun, besides suitable clearance, in order that the disappearance might occur at any angle of train. The 13-inch gun, for example, would require an interior diameter of something more than 40 feet in the barbette for a single gun, and about 48 feet for two guns if mounted with as much space between them as the Indiana's are. Thus the designer would be at once confronted with a most formidable weight problem in the amount of armor required for a barbette of such dimensions.

But granting that the weight problem of the enormous barbette could be solved, the architect would straightway encounter another one not less difficult, namely, that of providing for the disappearance and re-lifting of the gun or guns with mounts, turntable and shield, not only with the ship on an even keel, but also at any angle within her arc of rolling. I will not attempt to analyze the mechanical elements of this latter problem here. But it should be observed that the majority of men who conceive schemes in a general way take no thought of the problems of applied mechanics involved in their practical execution. In fact most of them are incapable of applying mechanical practice to the solution of any problem or to the execution of any scheme. They simply think or imagine or dream of something and then expect the practical mechanic to effectuate it.

I have given some attention to the subject of disappearing naval mounts for heavy guns, and the result of my study and calculations in this direction took shape in No. VIII of the schemes which I recently submitted to the Navy Department in my bids for battle-ships in Class II, A. I made no attempt, however, to arrange for complete disappearance of the gun or guns. The device elaborated made provision simply for depression of the breech to a certain angle by recoil, to a loading position within a barbette of ordinary dimensions for the caliber of guns involved, leaving the muzzles exposed as usual in all modern mounts, whether of the barbette or turret or shield type. Using the very long guns of the present day, I see no practicable escape from muzzle exposure. Returning to the Temeraire by way of example, it is to be noted that her disappearing guns are the old type of 25-ton muzzle-loaders, and very short in comparison to modern breech-loaders of equal caliber, or even of equal weight. It was therefore comparatively easy to provide a barbette large enough to house such short guns entirely by recoil disappearance. This suggests the idea that, perhaps, in battle-ships destined to fight at the closest quarters the length of even modern breech-loaders might be reduced without detriment to their real battle-power.

In conclusion I will say that while I think I have worked out a practicable plan of semi-disappearance or breech-depression to a point of mechanical satisfaction at which I was willing to submit it as a scheme accompanying a bid, I am yet not wholly without misgiving about it, and am not altogether prepared to recommend any disappearing system for naval gun-mounts in competition with any tried and proved system of fixed mounts, whether in turrets, barbettes or shields.

WILLIAM CROZIER,* Captain of Ordnance, U. S. Army.—The valuable action of a disappearing gun upon shore is that it drops, upon discharge or very soon thereafter, from an exposed position to one of greater security below. To compass this action, the only features about which military engineers have given themselves much concern have been those connected with the means of raising and lowering the gun. The elements of the security which is enjoyed in the lowered position, viz., a greater or less degree of invisibility and invulnerability, are so easy of attainment that they have been taken for granted without, thus far, any indication that too little concern has been felt in regard to them. But afloat the matter is very different; the mere statement why a lower position should be more nearly impenetrable or much less visible than a higher one, unless the lower position should be below the water-line, is not simple, and the complexity of the question as to the desirability at all of the disappearing principle afloat has been abundantly shown by the multitude of considerations which have been brought to bear in the able paper under discussion.

It may be assumed, from the experience had on shore, that if the secure lower position be provided, efficient means for dropping the gun into it will be forthcoming, although there may be room for difference of opinion as to the character of these means, particularly as to the relative merits of the general systems of the rocking lever and the vertical ram, to which I will allude briefly later. It is not for me, in my ignorance of naval construction, to indicate how a secure low position for the gun on board ship may be attained; but to criticise is much easier than to create, and to indicate the unsatisfactory envisagement of the question I will examine cursorily the sketch design of disappearing turret shown in Fig. 17, which the author presents as indicating, in a very general way, the plan which he has been led to regard as most feasible.

Considering the gun in the lowered position, suppose that portion of the armor plating of the fixed turret which is above the lower edge of the hood over the gun to be removed and distributed over the conical surface of the hood, increasing the thickness of the light armor of which the hood is formed; the protection in the lowered position is increased because, the surface of the turret removed being greater than the conical surface of the hood, the armor when applied to the latter surface will be thicker. If now we mount the fixed turret upon rollers, attach the gun and its carriage to it and suppress the lifting ram, we are back with our old friend the ordinary turret, having secured by the change constant protection slightly greater than that afforded by the disappearing turret to the gun in the lowered position and much greater than is afforded to it in the firing position; a saving of the weight and the complexity of the lifting mechanism, and an increased rapidity of fire by avoidance of the necessity for traversing to the lowering position, lowering, raising and traversing to the firing position. To offset these gains I cannot see that there has been any

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* Joint inventor and designer of the Buffington-Crozier system of disappearing gun mount.

sacrifice unless it be the less command of the gun than when in the firing position. But as the disappearing principle has not been mentioned as a means for obtaining increased command, I am not considering it with reference to that object.

The estimated rate of fire with the disappearing turret would require a high degree of perfection for its attainment. In a recent trial of the gun-lift battery at Fort Hancock, upon which are mounted two 12-inch guns having a vertical rise and fall of about 14 feet, produced by hydraulic ram mechanism, the rate of fire was one round per gun in something over eight minutes, the time required for raising or lowering, considered separately, being 15 seconds. As all hands engaged, though understanding their duties, were entirely without drill, the rate could probably be increased to one round per gun in about 6½ minutes. With the estimated rate the author makes it plain that the advantage of ability to fire over a lowered turret is probably more than offset by the diminished rate of fire. This probability becomes, I think, certainty in view of the results at Fort Hancock.

I have no data of the firing of a gun of as large caliber as 12 inches from a carriage of the rocking lever system, but a reasonably accurate estimate of the rate can be formed from the performance of guns of smaller caliber. An 8-inch gun was fired ten rounds at Sandy Hook from a Buffington-Crozier disappearing carriage at the rate of one round every 1.35 minutes, and a 10-inch gun from a carriage of the same type at the rate of one round every 1.67 minutes, the ratio of the rates being 1 : 1.235. The weights of the gun, projectile and charge for the 10-inch gun are about double those for the 8-inch. The weights for the 12-inch gun are about 1.75 times those for the 10-inch, so that the ratio of the rates of fire of the two, based upon these elements, should be somewhat less than for the 8 and 10-inch above stated, so that if, on the contrary, we increase the ratio to 1 : 1.5, we should not be overrating the 12-inch gun. The latter ratio would give a rate for this gun of one round every 2½ minutes. This is so much greater than the rate indicated by the experience at Fort Hancock for guns mounted upon vertically moving lifts as to probably more than offset the exposure due to the necessary final aiming of the gun when in the exposed position.

To a landsman the type of vessel upon which disappearing guns could be used to advantage would appear to require the following:

A complete belt of armor at least as efficient as is now provided, a central armored citadel, the lower edge of the armor joining on to the belt, and carried up as high as the available displacement would permit; guns of the primary battery mounted within the citadel upon disappearing carriages of the rocking lever system. These requirements would seem to leave latitude to the naval constructor in regard to the use of armored decks, building up the ends, disposition of the secondary battery, and so forth. The type seems to come out very much that of the Russian Catherine II, but it may be stated that with a rocking lever carriage a drop of 6 feet for a 10-inch gun would be a very moderate requirement, and the 4 feet given by Messrs. Easton and Anderson to the 12-inch guns of the Catherine II seems altogether inadequate.

It is with great diffidence that these remarks are advanced. The subject is one of such difficulty that no one unfamiliar with naval construction is in a position to deal with it.

J. E. COMPTON BRACEBRIDGE,* Captain Third Middlesex Volunteer Artillery.—I am afraid the questions under discussion are to be dealt with rather by the naval architect than by the gun-mounting manufacturer, but I personally do not think that disappearing turrets can be made use of on board ship. The mechanical difficulties are very great, and are increased by the long chases of modern guns, and the advantages are rather dubious. So far as we know, the mountings of the Russian ironclads have worked well. The great disadvantage of disappearing mountings on board ship is the exposure to plunging fire. No system of shutters for the hole through which the gun goes has been worked out, and they would be very liable to jam if struck. I was much struck by the remark as to the fondness of even a Japanese blue-jacket for a good upstanding target. It reminded me of the naval officer who announced that he intended on going into action to paint his conning tower bright scarlet and work the ship from the roof of the turret.

J. H. GLENNON, Lieutenant, U. S. Navy.—Leaving aside the question proper of the "disappearing gun afloat," which certainly does not at all simplify the already sufficiently complicated and delicate mechanisms of battle-ships—and simplification is the direction in which we are compelled to look—let us consider a little more closely one or more of Mr. Hobson's statements.

On page 631 we read: "To advance towards the equality of protection that would produce the highest resultant efficiency of the vessel, toward the infliction of the maximum amount of injury under the conditions for which designed, toward arriving under such intended conditions of engagements at the desired point where the offensive and defensive power would disappear together, when the last of the personnel and secondary battery would be destroyed, the vitals pierced, uprightness undermined, and the last heavy turret gun disabled at the moment that the vessel foundered, capsizing as the last vestige of buoyancy went under; to advance toward this ideal combination it would be more advantageous to expand effort available for protection in increasing the protection of the elements enumerated rather than in increasing the protection of the heavy turret guns."

This is a statement in some detail, plausible enough of course; in fact it belongs to a class of statements which we generally accept as incontrovertible. But inasmuch as it is given as the basis of a scheme

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* Expert for Easton, Anderson & Goolden Ltd., London, builders of disappearing mounts on the Russian battle-ships.

for armoring ships, we should look at it in some detail. Diminish the turret armor, increase by the same total weight the water-line armor, cease firing and slow down, allowing the enemy calmly and without excitement to approach closely, and three shots will do the whole thing, that is, effect the destructive combination quoted above. Battles on land seem to indicate that when seven per cent. of an army are killed it is time to retreat. I believe this was the rate at Waterloo, being nearly double that at Gettysburg. After the battles of seven per cent. we come by a sudden jump to those of approximately 100 per cent. like Cannae. This indicates to me that when about one man in 13 is killed a panic seizes on the others, and they are no longer of much value for fighting purposes. The element of human nature must be more fully considered. It seems to me evident that the above 7 per cent., or the panic stage, whatever that may be, should be coincident with the loss of stability and buoyancy, simply from the view of their protection alone. But we must not consider their protection alone.

It is impracticable to armor the sides and bottom of a ship sufficiently to keep out all the projectiles which will be brought against it, or even to approach closely this proper thickness necessary to protection of buoyancy and stability. An inch of armor taken from the side would mean several inches to the turrets with absolute security there. The increased value to the offense, in view of security, would alone probably be the equivalent, as a defense, to the inch of armor on the side, not to mention the saving of personnel and gun mechanisms as a desideratum. In other words, the men themselves and the guns are the equivalent defensively of so much side armor, and as they are destroyed, we must imagine layers of the side armor to be dropped off. All this is as regards guns alone. When we come to consider torpedoes, the fact of the security of the personnel and gun offense has much greater value than the side armor, for that of the latter is nil; offense, here the destruction of the torpedo while still on board the enemy, and the consequent restraint due to objection to being "hoist with one's own petard," being the principal, if not sole, defense. I will not go into the subject of the ram, as it is too intricate. The mind that guides the ram should certainly not be "rattled" or have arrived at the panic stage.

I am happy to say that in most of the other parts of his essay I agree with the writer; and I would like to compliment him, if permitted, upon the thorough analytical way in which he handles his subject.

G. W. Van Hoose, Esq.—The official report made by Assistant Naval Constructor Richmond P. Hobson on the model with disappearing turrets, which was presented to the Navy Department by myself, contains many suggestions and observations which are far-reaching in their consequences.

This report is divided into two general classifications:

First. A discussion upon the model and the proposed plan.

Second. A general discussion upon certain features of the present type of warships.

This last-mentioned branch of the subject, in my judgment, is as full of general interest to the student of naval warfare as the first would naturally be to myself.

This part of the report also clearly shows that Mr. Hobson is a practical thinker, and has been asking himself the grave question: What will the present type of warship do under a prolonged and heavy fire? He clearly thinks that the ship will, under many conditions, capsize and sink, with perhaps most of its turrets in good working order, and he demonstrates his conclusions in a most unanswerable manner.

In my judgment, a careful study of this feature of the report will repay any friend of the Navy, even if he does not believe as yet in the proposed new departure.

The writer of this article does not belong to the class of persons who see nothing good in the new Navy, but he recognizes the fact that the genius of America has begun to take hold of the great problem of the coming warship; and such creations as the Indiana, Iowa, New York, and similar types, reflect great and lasting credit upon their designers.

The model which was submitted to the Navy Department and referred to the Bureau of Construction and Repair, and which was most carefully studied and considered by the author of this report, was not submitted with the idea that it illustrated any fixed or even accurate plan. It was only intended to be illustrative and show in a general form a certain plan, which could be modified or changed to suit different types of warships.

A kind and courteous invitation had been extended to me to contribute an article upon this subject, but the time was so short that I could furnish nothing better than the following short reply, which had heretofore been filed in the Navy Department, and which explains my plan in certain matters of detail. Taking this in connection with the printed official report will fairly show the proposed system. After a most careful consideration, the Patent Office Department allowed the writer all his specifications and claims, thus confirming the statement of Mr. Hobson that the main idea was novel.

In reply to Report No. 5801, made by the Bureau of Construction and Repair, I wish to file a short statement in explanation of some matters of detail relating to my model of a warship.

The military tops or masts shown by the model are not intended to represent the tall military masts of the present battle-ship or cruiser. It is utterly impossible to raise or lower such masts, and I did not intend to suggest this mechanical impossibility. I only intend to raise and lower a circular platform as suggested by the report. This could be raised by means of hydraulic, pneumatic or pulley power. The model is intended to suggest a top which can be run up at critical moments a distance of 25 to 35 feet. The report concedes this to be a valuable idea. I believe that several of these military tops can be used to great advantage. They can be located in many parts of the ship without interference with the machinery below the water-line. The machine guns in these tops can also be fired from the upper deck in many positions of the ship. The model also indicates a number of strong girders extending above and across the upper deck. This formation is intended to support a developed platform, which will carry the search-lights and a number of rapid-firing guns to repel the attacks of torpedoes. It is intended that these girders should be strongly braced and connected, so that some of them can be destroyed by shot without undermining the superstructure. Its open framework will permit shot and shell to pass through it in many cases.

It would be perhaps advisable in a close and heavy fire to withdraw the men from this upper platform during its continuance, but the probabilities are great that enough of the guns will survive to enable them to be used to great advantage at some critical moment.

The model was made to illustrate a large battle-ship, but this was only illustrative. The system can be applied equally as well to coast-line battle-ships, or a special type of low freeboard coast-defense vessel.

I believe a low freeboard could be used to great advantage for river and harbor defense. The number and caliber of the guns would have to be proportioned to the tonnage of the craft.

The report seems to state that this system would *per se* cause the hull to receive greater punishment. I cannot agree to this as a mechanical necessity due to the system. I believe that it will be admitted that at moderate range most projectiles are fired high by inexperienced gunners, and that the upper works, such as smoke-stacks, masts, military tops, etc., will receive a great number of hits, but I cannot see how elevating the guns so as to invite fire on them will save the hull, if the enemy's crew are veterans and will aim at the weak parts of the ship.

The report, however, does point out with great ability the weakness of the protection to the hull, as compared with the turret, on the present type of ship.

My whole system is based in a great measure upon this idea. Armor 18 inches thick on the turrets cannot save the unprotected hull. The model is intended in a general way to illustrate a warship which can concentrate a superior fire upon an enemy of its class and overwhelm him with its battery power, and in this manner virtually protect itself.

The guns are not made to disappear simply to protect them. The main idea is to get them out of the way so as to double the battery power.

In my judgment, the whole of the main battery fire of this ship should be aimed at the hull of the enemy. The secondary battery could be aimed at the ports of the turrets.

I wish here to state that the type of ship represented by the model is intended to carry a very heavy secondary battery, but as I had nothing very distinctive to illustrate, I did not show this feature to any great extent on the model. The report, however, treats of this important feature with great fairness, and it also points out the various ways of arranging a powerful secondary battery.

The report points out certain defects in proportions of scantlings, beams, form of armor protection over the guns, as shown by drawings, etc. I am aware of all these defects, but I only intended to illustrate general ideas, and did not make any claim to professional accuracy on some of the details of the model.

The value of this system will depend upon good mechanism, as the report states; and I confidently claim that hydraulic power can be utilized to lift the weight of the guns and armor to protect them, and that it can be regulated with unfailing accuracy.

The report concedes that the direct lift is the best method of elevating the guns, and this was the only method that I intended to illustrate. No details were specified, for it will be evident that details would have been useless in a mere preliminary exhibition of a new system. However, I promise to bring forward a general plan to lift the guns upon a system which will meet all necessary requirements. I had foreseen that good mechanics would state that certain indispensable conditions existed, namely, strength to resist shock of projectiles, the shock of the guns in firing, the support of the guns while in their elevated position, and a constant supply of ammunition. This can all be done by strong, simple and effective methods. I am willing, however, to admit that expert designers must aid in this work, and I sincerely hope that this system will receive the aid of their learning and ability.

I do not approve of any system of lever lifts, because all such as I have seen leave the guns utterly unprotected, and besides, one set of guns cannot be fired over another set. While the weight lifted by levers is much less, yet this system is worthless in developing increased battery power. My main object is to destroy an enemy in a naval combat, and this must be done by directing upon him a heavier fire than he can return.

Armor will protect the ship where used, but so much of the ship is left unprotected that sea-going vessels will have to do their work quickly, or else the unprotected parts will practically be destroyed.

I anticipated that some naval men would object to giving up the present upper works, but this must be done to gain the great increase in battery power. This great offensive fire is after all the best protection to the ship carrying limited armor.

I believe that my patent points out and covers the field for concentrating upon an enemy a greatly superior fire with the same number of guns. The various ways of lifting the guns are detailed at length in its specifications.

Assistant Naval Constructor HOBSON.—In the valuable and interesting discussions above, the ideas advanced agree with and emphasize the conclusions arrived at in the paper, except in the following cases:

1. Where it is advanced in effect, (1) that the usual form of turret would present advantages over the form of disappearing turret sug-

gested as best fulfilling the conditions, though the latter had perfected mechanism; and (2) that the rocking lever system presents advantages over the vertical lift or simple rise for use on board ship as well as ashore.

2. Where it is advanced in effect (1) that in the existing battle-ships of usual types the hull is better protected than the heavy turret guns; and (2) that the issue of probable engagements will be determined more by injury to the personnel than by the other forms of injury inflicted and sustained. The first two cases affect the disappearing gun proper, the last two involve the broad question of relative protection and the distribution of armor.

I.

1. Turrets, whatever their form, are destined to perform an office for guns whose positions of emplacement are determined or fixed.

To compare two systems of turrets with a view to determining their relative merits, particularly with regard to the question of weight, they should be considered as fulfilling their office for the same guns in the same position. The weight of armor in any system varies directly with the height of the gun above the protective deck. To compare rationally the weight in two different systems this height must therefore be taken the same in both.

In the case sketched in Fig. 17, page 611, the guns must fire at a certain height above the upper deck. The turret shown as fulfilling this condition cannot be compared for weight with one of its own or any other type that leaves the guns below the level of this deck.

Obviously the conversion into the usual turret, referred to for illustration in the discussion, should be made with the guns in the raised, and not in the lowered, position as advanced. The fixed armor, which is the same as the fixed armor in the usual case of barbette or turret, must remain the same. The armor to increase the thickness of the light turret must be additional. The condition of weight becomes the same as set forth in the paper, a small reduction in the weight of additional mechanism, and a heavy increase in the weight of turret armor, a net increase of about 180 tons for two 12-inch turrets. Thus the usual system compared with the disappearing system in the figure referred to, instead of economizing weight as advanced in this discussion, entails a substantial increase.

2. In the lowered position the turret guns are protected by the armor of the barbette, practically equal to that of the movable turret in the ordinary system, increased by the armor of the light turret—equal to about ⅓ this armor—and in addition by their invisibility.

Opposing battle-ships are destined in the course of engagements to come into close proximity with each other, and it is at these critical periods that protection will be overmatched by the weapons. Pointing will require but a short time, and the disappearing guns would be but a short time in the raised position, with the possibility of this time being made to occur more or less when the enemies' guns are not ready for firing; while on the other hand, during the comparatively long period of loading which may extend, after firing, beyond the period of exposure, they will enjoy the protection of additional armor and invisibility.

In the critical periods of passage at close quarters this additional protection is of precious value. At such short ranges special targets will be selected, and their selection will play an important rôle in the issue, notwithstanding the allusions to the contrary contained in the discussions.

Invisibility, which is clearly the only method of protection practicable for the chases of modern guns, then becomes of enhanced value.

The maximum protection in the proposed system is thus seriously greater than the constant protection of the usual system, and is best available at the most critical moments, when weapons overmatch armor, and fire becomes accurate.

In view of this greater maximum protection afforded by the system, and in view of the fact that the minimum protection, occurring when the guns are in the raised position, overmatches the bulk of attacking weapons, while the time of exposure to weapons by which it is overmatched can be regulated at will to correspond to the probability of being hit, it becomes clear that the mean effective protection of the system is superior to the constant protection of the usual turret, which is overmatched by attacking weapons at critical moments of passage at close quarters and which, on the other hand, by virtue of inordinate weight, overmatches out of all proportion the weapons by which it is liable to be struck at moderate ranges.

Thus, for protection, as for weight, the advantage lies on the side of the proposed system.

3. The time required in the operation of turning to and from the position for lowering, the time for lowering and the time for rising depend on the efficiency of the mechanism. On the supposition of perfected mechanism, this time would bear but a small ratio to the time required for loading operations. Moreover, there is no reason why, after firing, the operation of opening breech, wiping breech plug, sponging powder chamber, and making other preparations for loading, could not take place during the time of turning to the disappearing position and during the lowering process, while at the same time charges and projectiles could be proceeding on their way up from the magazine; indeed, there is no reason why a lodging place could not be provided for charges and projectiles which would always be in readiness at or just below the position for loading; and then the process of loading need not detain the guns in the lowest position unless such detention is desired, for there is no reason why the features of this process could not be carried on during the process of rising and turning to the bearing of the enemy. Further, as set forth in the paper, the guns could be loaded in any bearing while in the raised position.

Thus, on the assumption of perfected mechanism, the disappearing property superposed would be practically independent of the service of the guns, except in the requirement involved by a single position for disappearing, necessitating turning, a process that is rapid and precise, and that could be rendered to a certain degree automatic if desired; and the time passed in the lowered position, practically or wholly lowered, would be regulated at the will of the mind in charge. When, then, the greater protection of the lowered position were utilized to its greatest extent, the guns descending after each round, and when at the same time the greatest execution with the guns were sought, the lowered position could be made to correspond to the necessarily inert period of the guns, causing but a very small reduction in rapidity of fire.

4. Turret guns mounted in the most advantageous positions on battleships have a dead angle of about 90°.

Nearly the whole of this angle, as pointed out in the paper, is necessitated by the other gun positions, and one of the main objects sought by the disappearing system is the redemption of this dead angle, amounting to nearly a quarter of the horizon. The risks that are liable to be incurred by firing over the positions of guns while below deck are pointed out in the paper, but the difficulty of providing against these risks is by no means of the order of the difficulty involved in the assumption of perfected mechanism for raising and lowering. It is easily conceivable that by the closing of electrical circuits means could be provided for automatically preventing any gun from firing when other guns would be endangered, or more simply for signaling such danger in a manner impossible to escape the notice of the gun captains.

The discussion advancing the ordinary turret against the disappearing system fails to refer to this redemption of the dead angle and consequent increase of the effective angle of fire.

5. In sum, on the assumption of perfected mechanism, the disappearing system presents for heavy guns serious, incontestable advantages, offers a material economy of weight, affords superior protection for which, in effect, the vertical column of armor is rendered telescopic with one or two thicknesses of armor available at will, to correspond to the degree of exposure, and increases substantially the effective angle of fire; while with all these advantages it necessitates but slight, if any, reduction in the rapidity of fire.

6. But the assumption of perfected mechanism is not warranted. Such a mechanism would require, not only a large source and reservoir of energy and a medium of its direct application, but also a transmission of this energy across joints broken by vertical rectilinear movement as well as horizontal rotary movement and its application on the far side of these joints to varied forms of appliances; and further, would exact with all the complexity, accuracy, and delicacy of these mechanisms and these joints great robustness and solidity to withstand the severe strains entailed by the varied movements of the vessel in a seaway and the shock of projectiles in action. The difficulties in the way of perfecting such mechanism are pointed out in the paper and are strongly depicted in the first discussion. Until they are overcome the advantages set forth cannot be considered as belonging to the system,

for, as pointed out, they are rapidly nullified as the mechanism departs from a high state of efficiency.

The assumption that efficient means of dropping a gun into the lowered position, and by inference of raising it again, would be "forthcoming" was made perhaps without consideration of the feature of raising and lowering armor with the gun, and of the limit of space imposed when a barbette of usual size is employed. The assumption was made probably with a picture in mind representing the simple problem of raising and lowering a gun mounted within a spacious redoubt as on the Russian battle-ships, the disposition afterward suggested as the one best adapted for the use of the disappearing gun afloat.

Reference need only be made to the total lack of cover and the entire exposure to plunging fire, even at small angles, particularly from fire from ahead and astern, to show how uneconomically this vast weight of armor is disposed, the exposure becoming greater as the extent and weight of armor increase. The heavy guns on these battle-ships will probably be disabled partially or wholly by the shower of rapid-fire projectiles, particularly those charged with high explosives, before the enemy comes within the range where the probability of hitting justifies the use of heavy guns. The protection for the guns in these vessels would be far greater if the redoubt were cut and the armor carried around into two barbettes; one enclosing the two forward pairs of guns, the others the after pair; even then it would be most advantageous to make covers or hoods revolving with the guns and having openings for the guns to pass through to protect these enormous barbettes from plunging fire.

The weight of such a barbette, large enough to receive a modern gun entire, would be enormous, as pointed out in another discussion; the two in the case cited amounting to about the weight of the entire redoubt.

Where, however, such an uneconomical disposition of armor is adopted, where such waste of weight is permitted, and where no effort is made to take up protection for the gun and gunner during the time of sighting, a system is readily "forthcoming"; and the lever systems, barring those which employ counterweights, advanced as the most suitable for use afloat, present all the advantages pointed out in the paper. But where armor is economized and a barbette of the usual size is employed, where no attempt is made to protect the robust chase of the gun otherwise than by its invisibility when lowered, where, further, substantial protection is provided for the gun and crew while in the raised position; when, in short, a turret with its guns is to be lowered into and raised from a barbette of but slightly larger diameter, a system is in no sense readily "forthcoming," while any lever system is obviously out of the question. A system of simple vertical rise is the only one possible. Thus far, hydraulics alone can offer any chance of supplying the power under the conditions imposed.

In connection with the comparison of the hydraulic system of simple rise and the lever system as made in the discussion, it is to be noted that the results of the practical test of the Buffington-Crozier 8-inch mount at Sandy Hook were excellent for time made, though this system of lever mount is precluded from consideration for shipboard use on account of its counterpoise feature which economy of weight prohibits, but it should also be noted that the time required for the rising and falling process for the hydraulic mount tested at Fort Hancock was also excellent, requiring but 15 seconds for each process, which time could of course be very much reduced in the lowering process, and it should be noted further in the comparison that the lift was 14 feet, no doubt double that of the 8-inch gun, and further that there were two 12-inch guns raised together mounted on a single platform, while the estimate for the lever mount was based on the weight of a single gun.

In sum, as set forth in the paper, the system of disappearing turret as embodied in the sketch plan, page 611, offers incontestable advantages, provided the mechanism is efficient; obstacles of a serious nature are confronted in any endeavor to provide efficient mechanism, while the necessity for efficiency is absolute; the conditions impose a simple vertical rise, for which hydraulic power is best adapted.

II.

The permeating object of design in a vessel of war is the realization of a maximum efficiency for each element of weight in its contribution to the ultimate object of enabling the vessel in the probable conditions of service to fulfill the rôle for which it is intended.

The apportionment of the total weight among the features is regulated by the degree of efficiency of weight assigned to each. When finally made, this apportionment should be such that no unit of weight could be transferred from one feature to another with injury to the efficiency of the whole.

The distribution of the weight assigned to a particular feature is governed by the same principle, and when finally determined, the conditions should be such that no element of weight could be transferred from the locality assigned it to another belonging to the feature without injury to the efficiency of the feature as a whole.

The question of the apportionment of weights is not treated in the paper and is not referred to in the discussion. However, assuming the apportionment made, the distribution of the weight assigned to armor protection is intimately involved. It is advanced in the paper that the heavy turret guns are better protected than the features classed together as the hull, and that additional weight and expense, if available for armor, should be assigned to hull protection. It is advanced in the discussion, on the other hand, that in effect the hull is over-protected in comparison with the protection of the guns, and that it would be advantageous to transfer part of the hull armor to the guns. It is further advanced by partial inference that casualties to personnel will constitute the main factor in determining the issue of engagements, a conclusion not altogether in accord with inferences to be drawn from the conclusions arrived at in the paper and from considerations pointed out below.

It is not necessary for the present purpose to enter at length on the evaluation of the efficiency of the armor weight assigned each feature or element in the usual battle-ship.

In order to arrive at a general conclusion as to the relative protection of the hull and of the guns, and as to the advisability of a different distribution of armor weight, it will suffice to point out simply the salient features involved.

III.

Armor Weight assigned the Guns.

1. The efficiency of any element of armor weight protecting any feature is measured by the demand for protection, resulting from the importance and the vulnerability of the feature, and by the effectiveness of armor in supplying this demand.

2. (1) Every element of offense partakes essentially of the nature of defense from its silencing effect on attacking weapons. In consequence, the quantity representing the importance of the guns should have an enhanced value, a greater exponential weight. But it is to be noted that the silencing effect varies in importance inversely as the degree of armor protection of the enemy's guns, being greatest where protection is least, as in unarmored and unprotected vessels, and in partially protected and unprotected guns, and least where the protection is greatest, as in battle-ships and armored coast-defense vessels, and in heavy turret guns. Thus, though the dual nature of guns is an important consideration, it affects worst the cruiser classes, while on battle-ships it affects most the medium caliber and light guns.

(2) The value of a gun attacking armor passes rapidly from practically zero when the gun is overmatched, to a high maximum when the armor is effectually overmatched. The maximum is practically reached at the present stage of the development of explosives when the gun can drive an explosive projectile through the armor so that its explosion takes place on the inside, which at present may be considered as taking place when the caliber of the gun approaches twice the thickness of armor.

When this point is reached, further increase of caliber is disadvantageous as far as the particular armor is concerned, being advantageous only where there is other armor to be attacked beyond the first armor.

When the armament of a battle-ship has been determined by this principle, and a developed battery is carried that overmatches the light armor of the usual battle-ship in the sense of being able to drive a semi-armor-piercing projectile whole through it, then such a battery, without diminishing the value of the heavy guns, must be ranked alongside of them in first importance, in view of the vast area of light side armor now carried and the grave features it protects. It follows, then, that such a battery should receive an equal consideration with the heavy guns in determining the distribution of armor.

It is interesting at this point to note that the principle above enunciated is followed only in the case of our three battle-ships of the Indiana class, though with these vessels it cannot be said that the principle is wholly carried out on account of the armor for protecting the 8-inch guns not being proportioned to their importance, being of insufficient thickness, and not extending to the casemate armor; while our other three battle-ships, the Iowa, and the Kearsarge, and Kentucky, attain, after the Indiana class, a nearer approximation than any other vessels built, building, or designed.

The Iowa falls short on account of the caliber of her heavy guns, 12-inch, not outclassing the usual heavy armor whose thickness is designed in view of this caliber; though, on the other hand, the 8-inch battery, with barbette armor extending to the level of the casemate armor, approaches nearer the required degree of protection, while the Kentucky and Kearsarge fall short in having but two 8-inch turrets instead of four, and having these hampered in their independence of action; though, on the other hand, an increased thickness has been given the armor protecting these guns, making their protection accord more nearly than in the other vessels with their importance. It should not, of course, be lost sight of that these last two vessels have superposed a more developed rapid-fire battery which would be very effective if vessels of the cruiser classes came within range in a general engagement where the silencing effect of this battery could be effectively employed. The Iowa approaches very near to being an ideal flagship for a fleet of the Indiana class; she would be an ideal battle-ship as far as battery is concerned if her 12-inch guns were 13-inch, and the thickness of armor on the 8-inch turrets were increased 3 inches. To make the Kearsarge and Kentucky approach the same ideal it would be necessary to add two more 8-inch turrets, one on each waist, completing a lozenge. In both cases there would have to be an increase of displacement and cost, though, if necessary, about ⅓ of the 5-inch battery of the latter vessels could be sacrificed to furnish part of the weight.

It is of further interest to note that the system of hull armor now adopted in English construction, studied on the Renown and developed on the Majestic class, is an effectual reply to the semi-armor-piercing projectiles, referred to as influencing the thickness of armor.

The 8-inch gun is overmatched entirely, and heavy guns can penetrate only with armor-piercing projectiles, whose destructive effect is not comparable with the destructive effect of explosive projectiles.

This veritable fleet of battle-ships, created at one call to the English nation, of themselves alone exceeding by ½ the number of all our battle-ships yet authorized, is comparatively invulnerable, and will remain so till a semi-armor-piercing projectile can be counted on to pass whole through 9 inches of armor.

Returning to the point established above, the heavy guns in an armament designed for use against all systems of armor now existing, except the one referred to above, now adopted in England, shares the first importance with the guns of next lower caliber, and should share with them the first consideration in assignment of armor weight.

3. (1) The mechanism, supports, communications, personnel, and other accessories of the heavy guns are of great innate frailty for resisting the attack of weapons and demand an absolute protection. This demand, however, is fully met by the barbette or fixed armor as far as its protection extends.

(2) The vulnerability of the gun proper is small, and as far as its protection alone is concerned the protection of heavy armor as carried in the usual turret is altogether inordinate.

(3) If the personnel, mechanism, and accessories could be abstracted from the gun and could be placed and could remain below the level of the barbette, while an armored hood or cover, revolving with the gun platform, covered the top of the barbette, then the demand for a revolving turret would not exist, provided the breech plug and its vicinity could be protected during the operation of loading by having the breech sink below the level of the barbette cover, as provided for in the most interesting semi-disappearing gun-mounts referred to in the discussion as submitted in one set of plans proposed in bids for battleships 5 and 6, or by means of vertical hood armor rising over and extending to the rear of the breech, carried by the revolving armored platform forming the cover of the barbette.

In sum, the gun itself is robust and but slightly vulnerable, while its mount and all accessories are frail and very vulnerable. Heavy armor is an absolute necessity for the protection of the latter, but is not required for the former, and in consequence a heavy revolving turret is not necessary if other heavy armor protection is available for the mount and accessories.

(4) For the turret guns of medium caliber the vulnerability is precisely the same as pointed out for the heavy guns.

4. (1) The natural envelope of the supports and accessories of turret guns is a vertical cylinder of moderate diameter of section.

(2) A vertical cylinder lends itself most advantageously for the application of armor, for it presents as a projected target a mean angle of impact of large obliquity, while its form is self-sustaining.

The armor applied to the protection of the heavy guns is thus most effective, presenting its face obliquely and sustaining itself by its inertia and the support of its own parts.

(3) The same observation applies with even greater force to the armor of turret guns of medium caliber.

5. Thus, in sum, in evaluating the degree of efficiency of armor weight assigned to the protection of the guns, the following facts are to be considered:

(1) For the barbette or fixed armor, the demand for the protection it affords is absolute, nothing but armor protection is available, and armor applied is effective; in consequence, armor weight applied to such barbettes or fixed turrets has a high degree of efficiency. In the case of heavy guns, the thickness of barbette usually adopted is sufficient,

outmatching the heaviest calibered guns, and, in consequence, but slight advantage would be gained by increasing the thickness, while decreasing it would incur disadvantage.

In the case of medium caliber guns which overmatch light armor, this barbette in usual cases is insufficient in thickness, in some cases does not extend to the protective deck, in others is altogether lacking. The protection of such guns is not commensurate with their importance, their vulnerability, and the effectiveness of armor so applied.

(2) For the turret proper or revolving armor there is but slight demand for its protection from the gun proper; and for the accessories and personnel, which require such protection, it is possible to make other provision in the case of the heavy guns, though this is impracticable in the case of medium caliber guns, whose mechanism is grouped in close proximity to the gun itself.

Where, however, the heavy turret is employed, it is to be observed that the vulnerability of the accessories grouped near the gun is less than that of those below in the barbette, the personnel accessory being capable of relief, being replaced when injured. The thickness of armor employed, somewhat greater in usual cases than the thickness of the barbette armor, is not well proportioned to the demand for protection. It should be observed, however, that as long as any such turret is retained there should be an endeavor to place the accessories below in the barbette as much as practicable, and to dispose them in such a manner as to be the least vulnerable when retained in the turret; but even then the thickness should never be reduced, in a vessel expected to engage at close quarters, below the figure which gives perfect immunity from the penetration whole of any explosive projectile, or below the figure which excludes under all conditions all projectiles from guns other than the heaviest, not considering, of course, the case of a turret that has recourse, when needed, to the protection of the barbette and of invisibility. For a design at the present moment 10 inches would be such a minimum, this being a safe figure probably for some time to come.

On the other hand, with the medium caliber guns destined to overmatch light armor, carrying the vulnerable accessory more with the gun, the thickness of armor is insufficient, and as in the case of the barbette, is not properly proportioned to the importance and vulnerability of the guns and the effectiveness of armor applied to them.

In sum, a high degree of efficiency is enjoyed by the weight assigned to the barbettes for heavy guns, but a lower degree only belongs to the revolving turrets proper. A high degree belongs to the armor weight assigned for both barbettes and turrets for medium caliber guns, but the quantity of weight is insufficient.

There would be advantage in reducing the weight assigned to the heavy turrets and in increasing the weight of armor assigned the medium caliber guns.

As concluded in the paper, there would be no adequate advantage in increasing the weight of heavy turret armor, though there would be advantage in increasing the protection of the guns taken as a whole, this increase taking the form of increasing the protection of the medium caliber guns, which latter question is not treated in the paper.

IV.

Armor Weight assigned the Hull.

1. The great importance of the features protected by hull armor need not be entered into, being apparent. It will suffice to point out that the integrity of each one of these features, floatability, stability and uprightness, and vitals, is essential, not only to the use of the guns, but also to the use of the torpedo and ram, to the very existence of the vessel.

2. (1) The vulnerability of the features of floatability, stability, and uprightness is set forth in the paper, and not being questioned in the discussion, need not be entered into again. It will suffice to recall that the portion of the hull through which the enemy of all these features, the great enemy of all hollow floating bodies, the ever ready water, may enter has but a fraction of its area covered by armor. It will suffice to recall that but a fraction of the hull liable to alternate immersion and emersion is covered by armor, that vast areas are at the mercy of projectiles and fragments of all kinds, which coursing along the side can cut open long gashes, or flying outboard tear off whole lengths of plating, laying the wall open to the entrance of water, while the portion with armor is but partially exempt.

(2) But the vulnerability of the most important of all features, the vitals, should be looked at more closely. These comprise the organs of locomotion and explosive objects, including compressed gases as well as explosives proper.

The nature of all of these objects is most delicate, most susceptible to derangement that would cost the ship its existence; their protection, if possible, should therefore be absolute. In their position below the protective deck they are liable to injury from above and from the sides.

Wherever a deck, however heavily armored, can be reached by explosive projectiles it is liable to disruption, and it can be laid down as a principle for the present stage of naval progress that when a protective deck worked near the water-line can be reached by a projectile entering at an angle of fall of 7° from any bearing without first encountering armor, or where the side armor above it is outclassed by semi-armor-piercing projectiles, or where the side armor below it is outclassed by armor-piercing projectiles, then an armored deck must be worked below it; and inversely, where there is no armored deck worked below the protective deck situated near the water-line, armor must be placed so as to intercept a projectile entering at an angle of 7° from any bearing before it can reach this deck, and the side armor above this deck must outclass all semi-armor-piercing projectiles, and the side armor below this deck must outclass armor-piercing projectiles, or else the protective deck must descend at sides to the lower edge of this armor.

The first conditions are fulfilled only by the five latest French battle-ships, now building, the Masséna, Bouvet, Charlemagne, St. Louis, and Gaulois; the last conditions are fulfilled only by the nine latest English battle-ships, the Majestic class.

In all other vessels yet built or designed, including all of our own battle-ships, there is no armored deck below the protective deck, and at the same time the light side armor is outclassed by semi-armor-piercing projectiles, which are thus liable to reach the protective deck and explode in contact with it and hurl fragments below into the fragile or dangerous vitals, while the protective deck is exposed further in a greater or less degree to the explosion in contact of projectiles entering above the light side armor, particularly from bow and quarter bearings on which the turrets would not be encountered, and such explosion would blast the deck in the region, likewise hurling fragments on the dangerous mission into the vitals.

It is interesting to note that the disposition on the French vessels referred to, which were the first designs to fulfill the conditions above which provide for a lower armored deck at the level of the lower edge of armor, will provide greater security for the vitals, though it will admit greater internal destruction above, while the disposition adopted in the English vessels, though giving a less guarantee for the vitals, will reduce to a very great degree the internal destruction by excluding all explosive projectiles, by the uniform thickness, 9 inches of side armor.

The fact should be taken account of, however, that development is rapid along the line of explosive projectiles, while the life of a vessel of war is long.

The day is probably not very far distant when 9 inches of armor will be overmatched by semi-armor-piercing projectiles, while there is certainly progress already for the penetration of armor by projectiles carrying high explosives. The English disposition, though perhaps offering better advantages for to-day, will tend to become obsolete, while the French disposition is good for all time.

Thus, in all vessels, with the exceptions above enumerated, the vitals are seriously menaced from above.

But their exposure is not limited to this direction alone. It was pointed out in the paper that the lower edge of armor emerges in the usual cases at an angle of roll below 10°, while the vessels would engage when rolling double that angle. In only a moderate seaway, when the vessel rolls but moderately, or where a wave trough passes along the sides, there will be exposed large unarmored areas below the lower edge of armor abreast the vitals.

In evaluating the time element to which the thickness of armor should in general be proportioned, it is to be remembered that the exposure takes place at the ends of the roll, where the pendulum lingers to reverse its swing, and though in this interval the probability of the unarmored zone being hit is small for the slowly-firing heavy guns, it is larger for the multitude of smaller calibers in proportion to their number.

Along the vast area of this exposed zone there is no obstruction to impede even the smallest rapid-fire projectile from reaching the magazines and steering engine and gear, while the coal obstruction abreast the boilers and engines is inadequate against rapid-fire projectiles of even reduced calibers. This exposure of the vitals from the sides, which appears in rolling, not infrequently experienced even in the usual sea swell, grows rapidly in seriousness as the sea rises, and in but a moderate fighting seaway becomes by far the greatest menace to the vessel of usual type, whose power of locomotion, whose very existence, stands a free though intermittent target to guns of practically all calibers.

This weakness is an attribute of the battle-ships, built or designed, of all nations. It is less pronounced in those destined to engage in the relatively smooth waters of the Mediterranean. Even for these waters the limit of 4 feet 11 inches set by the French for the desired depth of the lower edge of armor is insufficient, as are also the ameliorations adopted in recent English practice, 5 feet 6 inches in the Royal Sovereign class and 6 feet in the Majestic class, which with larger beam are destined for the high seas. As for our own battle-ships, the designed depths adopted for the lower edge of armor, 4 feet 6 inches in the Indiana class and the Iowa, reduced even to 4 feet for the Kearsarge and Kentucky, are better suited for still water than for the western Atlantic.

Thus the vitals, notwithstanding their careful location below the water-line and below the protective deck, are exposed from above and from below, and being of fragile and dangerous nature, constitute the most vulnerable feature of the usual type of vessel. Thus, for floatability, stability and uprightness, and for vitals, the hull in the usual battle-ship is in the highest degree vulnerable.

3. (1) Each kind or disposition of hull armor, heavy side armor, light side armor, deck armor, must extend over a large area to be effective even in a small degree for the protection of floatability, stability and uprightness, or vitals.

(2) The vertical armor has approximately a plane surface, presented practically normally on certain bearings; it is not self-sustaining, requiring special structural supports, which are of slight efficiency when a shock is received from the inside, an occurrence liable to happen with the light side armor, particularly when the enemy is employing armor-piercing projectiles, which, making but small breaches on the side of entrance, may drive whole armor plates overboard on the other side. The deck armor offers an advantageous oblique angle of impact, but is not supported sufficiently to realize anywhere near its full resisting power.

(3) In sum, the degree of effectiveness of hull armor, spread over large areas and inefficiently disposed, is small in comparison with the degree of effectiveness of turret armor.

4. Thus, in sum, in evaluating the degree of efficiency of armor weight assigned to the protection of the hull, the following facts are to be considered:

(1) The importance of the features protected is commensurate with the importance of the vessel itself.

(2) The vulnerability of the feature is great, and increases as the sea rises, when the demand for protection becomes absolute.

(3) Though subdivision, water-excluding materials and obturating materials are available for the partial protection of floatability, stability and uprightness, features overthrown by the entrance of water, armor alone is available to supplement the sea outside in the protection of the vitals against the violence of missiles.

(4) For protection from injury from above, the vitals demand either an immunity for the protective deck from explosive projectiles, an immunity that can be insured only by an adequate height of side armor of sufficient thickness to exclude explosive projectiles, or else an armored deck below the protective deck.

(5) For protection from injury from the sides the vitals demand, in the case of vessels on the high seas, armor on the sides extending to a greater depth than in any vessel built or designed, a depth in usual cases such that when floating at the designed water-line a roll of 15° should not emerge the lower edge of armor.

(6) The effectiveness of armor weight applied to hull protection is not great, the armor being spread over large areas, which form only a fraction of the areas necessary to be armored to insure security, and the disposition on these areas not furnishing a high degree of efficiency.

(7) Thus, in the case of the hull, the demand for armor protection is absolute, but the meeting of this demand can at best be but partial on account of the ineffectiveness of the armor weight thus employed.

In sum, as advanced in the paper, the hull is but partially protected, and the protection becomes more and more inadequate as the sea rises, notwithstanding the reduction in the number of hits. The demand for protection is great, the feature being of the first importance and in the highest degree vulnerable, but the reduced effectiveness of armor renders the meeting of the demand most difficult, the weight of armor being limited. In the usual vessel this demand is not adequately met, though full weight be given to the difficulty of meeting it, for the vitals in particular lack provision for protection which they must have to enable the vessel to fight securely in a seaway.

Not only should any additional weight available be assigned to providing a lower armor deck and extending the depth of the lower edge of side armor, but armor weight variously distributed in usual vessels in other localities would be more efficient so applied.

V.

Comparing the results arrived at in considering the efficiency of the armor weight assigned the guns and the hull respectively, the following deductions are to be drawn:

1. Due principally to the greater effectiveness of armor applied to turrets, the latter should be to a certain degree more highly protected than the hull.

2. This degree is fully reached by the fixed armor, the barbettes of the usual heavy turret guns; it is overstepped by the revolving armor, the turrets proper of these guns; it is not fully reached for the barbettes and turrets of the medium caliber guns that outmatch light armor. With the proper apportionment among the guns, the protection as a whole would overstep the proper degree of superiority. A surplusage of weight would be available for the hull.

3. The vitals are not protected in due proportion with the usual vessel; another deck should be worked over them and armored, and the sides should be armored to about double the usual depth with reduced and tapering thickness.

The weight for the deck could be partially supplied with advantage by reducing the upper or usual armor deck, and the weight of additional depth of armor could be partially supplied with advantage by reducing by about one-fourth to one-fifth the maximum thickness of the heavy belt and tapering it to 3 inches at the lower edge. The additional weight required should be supplied for the surplusage from the heavy turrets; the insufficiency then remaining should be taken from the upper part of the light side armor, and from battery armor not included in turrets, if additional displacement is not available for armor.

If the draught will not permit of two armored decks over the vitals, then a disposition should be adopted resembling that on the Majestic class, with side armor extending from 10 feet below the water-line at a thickness of 3 inches tapering to a maximum thickness of 10 inches at the water-line and thence to a thickness of 5 inches at a height above the water-line permitted by the weight, with the single protective deck dropped at the sides to 5 or 6 feet below the water-line.

As advanced in the paper, the heavy turret guns are over-protected. Any additional weight available for armor should be applied to the following purposes in the order named: 1st, to increasing the depth of side armor abreast the vitals; 2d, to working a second armored deck over the vitals; 3d, to increasing up to 10 inches the thickness of the turrets of the guns designed to outclass light armor and protecting its supports; 4th, to erecting transverse bulkheads, partial or complete, armored with special hard 2-inch armor to explode high explosive projectiles coming from forward and aft; 5th, to increasing the height of light side armor if already a complete belt, or completing it if incomplete.

It may be added that in the case of existing vessels with insufficient depth of belt and without the second armored deck on which, of course, the above provisions cannot be made, the security can be increased by sacrificing some weight of coal or other feature, and by working a strip of 3-inch armor about 5 feet wide on the wing longitudinal bulkhead on each side of the vessel abreast the magazines, with its top at the level of the lower edge of armor, and by working 2 inches of armor of the same width abreast the engines and boilers, the same being supplemented by the coal; the armor to be of special hard quality, and due provision to be made for its securings and support; in addition to this, athwartship bulkheads of light hard armor to be worked as described above to prevent high-explosive projectiles from reaching the protection deck.

VI.

1. The discussion which advances the proposition that the guns are under-protected compared with the hull advances also that injury to the personnel will be the principal factor in determining the issue of coming engagements, and that the desired co-ordination of protection should be made in view of a certain panic era of the personnel of the guns' crews, rather than in view of the silencing or destruction of the guns.

The drawing of such conclusions from the examples of history, as done in the discussion, is liable to be found illogical, for when examined closely the conditions existing on board vessels of war will be found radically different from those that existed on the vessels that fought the battles of history. The structure that was then a simple hull with platforms carrying a homogeneous cargo of men and guns with a simple function to perform, is now becoming a complex body filled and ramified with organs and objects of all degrees of power and all degrees of delicacy, performing functions of varied nature and of all degrees of complexity.

The motive power has been transferred from the upper deck to a position below the water-line, and though reducing the number and exposure of the personnel, has introduced a series of delicate and dangerous vitals along a large proportion of the vessel's length.

The open decks have become subdivided, and the once numerous personnel in close contact, having now recourse to mechanical power, has been reduced to less than half its former number and is distributed in small groups almost entirely isolated from each other. In addition, in the case of armored vessels, which constitute the bulk of power whose fate will decide the issue of engagements, the conditions of resistance are radically different. In the battles of the past the projectiles found no objects that could resist them—no places above water they could not enter. Now, the localities containing important elements offer resistance of varying degree. When these localities are confined in extent, as those containing the heavy guns, the resistance is made to overmatch all weapons, and these localities, with but a small fraction of the personnel, concentrate within their security the bulk of the vessel's offensive power.

With these radical differences in conditions it is hardly warranted to draw extensive inferences. It is the utter inadequacy of the past to throw light on the subject that causes the world's imagination to be haunted and the intellects of naval students to be baffled by the phenomena that are to take place when these gigantic creatures, evolved by the nations, meet each other in mortal combat.

It is not necessary for the present purpose to enter at length on this broad subject, particularly in view of the limits of the discussion in question and of the applicability of the conclusions arrived at in the paper and in the reply above. It will suffice in order to arrive at a conclusion as to the part to be played by the casualties to signalize certain additional considerations.

2. (1) A large portion of the personnel is stationed below the protective deck. On the Indiana, whose motive power requiring men below is very moderate compared with the battery power requiring men above, out of a total number of 462 officers and men, 206 are stationed below the protective deck in action. This large portion is abstracted from casualties and is identified with the vitals.

(2) Of the officers and men stationed above the protective deck, the greater part are well protected, the protection increasing with the importance of the function. On the Indiana, out of the 256 men stationed above the protective deck, only 24 are without armor protection, and these have the duties least necessary and are widely scattered; 26 have the partial protection of the armor protecting the 6-inch guns, being distributed in 4 groups at considerable distance from each other; 52 are in the 8-inch turrets, in 4 groups entirely isolated from the rest of the vessel; 28 are in the 13-inch turrets, in two groups entirely isolated, and comparatively speaking, enjoying absolute security.

(3) The casualties will thus not only be moderate and take place among those who least affect the vessel's welfare, but they will have no effect to speak of on the rest of the crew, particularly those associated with the important guns, who will be in entire ignorance of casualties outside of the turrets. A panic can take place only when the hull is injured, affecting the ship as a whole, and then it will be greatest below the protective deck, where there would be the fear of being imprisoned if the vessel went down. The vitals, not the guns, would be neglected before real destruction took place. In regulating the co-ordination of protection, if consideration is given the possibility of a panic, it should cause the addition of protection to the hull, not to the guns as advanced.

(4) The exposure of the personnel on the Indiana is thus as follows: for motive power, no exposure; for the 13-inch guns, 22 men in the magazines, no exposure, 28 men in the turrets, practically no exposure; for the 8-inch guns, 24 men in the magazines, no exposure, 52 men in the turrets, exposure to heavy guns only; for the 6-inch guns, 10 men in the magazines, no exposure, 26 men partially protected; at machine guns, 6 men with slight protection; wholly exposed, as above, 24 men.

Thus a battle-ship may be considered as having her motive power exempt from the effect of casualties, her heavy guns practically exempt, her medium caliber guns partially exempt, and the other personnel exempt in proportion to importance, while danger of panic can arise only from injury to the hull, when the vitals, not the guns, will be most affected.

Thus in sum, the issue where battle-ships are engaged will be but slightly affected by casualties to the personnel.

3. It is injury to the hull that will determine the issue in usual cases. The form the injury will take, whether sustained by floatability, stability, uprightness, vitals, or by combinations of these features, will vary with, and should be studied for, each individual vessel; it will be seriously affected by the condition of the sea and by the manner in which the attack is made. Taking our own battle-ships for examples, and speaking broadly, it will probably be injury to the vitals that will decide their fate. They will probably blow up from a boiler or magazine explosion, or have the engines or steering gear wrecked; the Indiana, Oregon and Massachusetts will probably have their stability overcome and turn turtle, if not first disabled or destroyed by injury to the vitals. In each case, all of the heavy turret guns and a part of the 8-inch guns, the proportion being greater as the sea runs higher, will probably still be in action when the end comes.

A. CRONEAN,* Naval Constructor, French Navy.—The objections raised by Assistant Naval Constructor R. P. Hobson, U. S. N., to the adoption of disappearing guns are of the most serious kind.

I wrote, a few years ago, in my essay on Guns, Torpedoes and Armor:† "The protection to be given to the water-line is proportionate to the protection afforded to guns. . . . If ships are constructed in which the guns have little or no protection, it will be sufficient to give the water-line comparatively small protection. The danger of sinking or turning over must be just a little less than that of having all the guns on board disabled one after the other." As it is easier to protect a gun by thick armor than to protect the hull, the weak point of modern war vessels is consequently (as Mr. Hobson clearly points out) the protection of the vessel itself, either below the water-line or a little above. An increase of protection to guns is then by no means to be wished for, at least in the present state of things, unless it should be obtained without any increase whatever of obstruction or weight.

Now, it is obvious that the introduction of disappearing guns on board ships would necessitate new organs, which would render a modern warship more obstructed than ever. A vessel of war may be compared to a sort of clockwork, the different "movements" of which are not to be multiplied *ad infinitum*.

As far as regards weight, it seems to result from Mr. Hobson's note that, in some cases which it is beyond our purpose to examine, some advantage might be gained by the adoption of the disappearing gun. This, however, in my opinion, would only hold good for coast-defense vessels. Mr. Hobson himself (see page 610) makes a distinction between coast-defense vessels and sea-going battle-ships. With the former, the gun remaining at the same level, we can, if we suppose that it will be raised only for a very short time, reduce the thickness of its armor,

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† "Canons, Torpilles et Cuirasse."

taking for granted that there is less danger of its being struck. In that case some advantage might be gained. But, if the ship under consideration is a battle-ship, as the fitting of a medium caliber battery will oblige the constructor to place his turrets one deck higher up than in the case of a coast-defense vessel, the aforesaid advantage must needs prove to be a mere loss. Judging from the sketches, the pit is protected by very thick armor, as thick as that of the armored turrets for the heavy guns now in use; and indeed it ought to be so, for a fragment falling into the pit might prevent the turret from rising and revolving, and consequently disable the gun. But that pit is larger than one of our modern turrets, not only in breadth, but also lengthwise, since it must be long enough to house the chases of the guns. In short, the protection to pits has the same height as the armor of one of the Iowa turrets, and a larger horizontal section; it then weighs more, and as the weight of armor of the moving part and the weight of the hydraulic raising gear have still to be added, the increase will indeed be considerable if the use of that system is not strictly limited to coast-defense vessels.

I have but little to say as regards the increase of defensive power. On shore the disappearing gun is rational, because as soon as it has disappeared, the projectile which would have struck it falls further on, with little or no damage. On the contrary, on board ships the gun cannot be considered apart from its floating carriage. It may be hoped that modern turrets, besides shielding the gun from the shots that strike its armor plating, will in some measure protect the decks and hull. But the disappearing turret would by no means afford the same protection, since in most cases the vessel would be reached instead of the turret, and the damage would be still greater.

The most interesting point of Mr. Hobson's paper is that the constructor might seek to obtain through the adoption of the disappearing gun an increase of offensive power by increasing the arc of fire so as to avail himself of the successive disappearance of the guns immediately after firing. Mr. Hobson's remarkable calculations give us a correct idea of the importance belonging to the improvements of the raising gear. In this there may be some theoretical advantage. But, practically speaking, it would certainly be difficult to avail one's self of the advantage thus gained. The period of loading would not be exactly the same for two turrets of equal caliber; the rise and fall would be more rapid with one than with the other, and turret No. 1, when raised, would hide the enemy from gun No. 2. Besides, it will be difficult to avoid delay in the command of the two turrets, especially if the commanding officer bears in mind that one of his guns may fire upon the other in case of slow working of the turrets, or simply if his commands have been misinterpreted. Moreover, circumstances will happen at sea in which all the guns on board cannot fire; in bad weather, for instance, the aft gun alone will be available. In such cases there would be considerable loss of time if the gun had to disappear after each round; or otherwise safety would be diminished if the gun remained in its firing position, since we take it for granted that the thickness of plating of the moving part would be reduced in disappearing turrets.

Besides, it seems probable that, in an engagement, an officer who has been for some time in command of his vessel will prefer using his turrets in their firing positions, and will altogether renounce the questionable advantage to be gained by the increase of offensive power.

On the other hand, Mr. Hobson clearly states that the increase of offensive power would be of some importance, especially for heavy guns, such as the "Peace-maker," for instance. In this discussion Mr. Hobson compares the quantities of energy developed in a given time by two guns, one of 8-inch, the other of 12-inch, and concludes as follows: "To make the comparison more complete, a factor representing the relative qualities of the two energies should be introduced. This factor would vary in each engagement with the nature of the target, depending upon its relative vulnerability to hostile energy in the form of 12-inch projectiles and 8-inch projectiles in movement. It will be sufficiently accurate for the present purpose to assume that the average target with which the vessel is designed to engage is equally vulnerable to the two kinds of energies, that the quality of unit quantity of energy is the same for both batteries."

In this assumption Mr. Hobson is quite right. Though it would be beyond our purpose to examine whether the target would indeed be equally vulnerable to the 8-inch and 12-inch guns, I think that guns below the 12-inch caliber can be used with advantage to-day. Then, if the 12-inch gun is too heavy, and lighter guns are better suited to the purposes of modern war, there is no reason why we should have recourse to mounts which would only be advantageous in the case of heavy guns firing a comparatively small number of rounds.

In short, the adoption of the disappearing gun on vessels of war, though interesting in the theoretical point of view, seems, practically speaking, to be especially suited to vessels armed with heavy guns and exposing a reduced target to hostile fire—to vessels of the Katahdin type, which, instead of being ram-ships, would be changed into monitors. This, at least, seems to clearly result from Mr. Hobson's interesting paper.

Assistant Naval Constructor HOBSON.—The above interesting and valuable discussion arrived after the reply to the other discussions had been prepared. This reply, however, requires no modification, for the discussion is covered by the remark at the beginning of the reply, that the ideas advanced agree with and emphasize the conclusions arrived at in the paper. There is one exception, however, though it proceeds from the misinterpretation, the one likewise made in the first discussion, that the treatment of the paper in its consideration of the general principles was intended to apply to the pear-shaped barbette shown as inclosing the entire gun. Fig. 13, page 609.

This figure was suggested to accompany the inventor's sketch and illustrate how it would appear when reduced to the form of a possibility. The protection by heavy armor of the robust chase of the modern gun, with its oblique surface, narrow rectangular target drawn out horizontally, is not desirable, and the increase in weight of armor involved is altogether inadmissible. It is not the disposition shown in this figure, but that of the figures on page 611, which is treated in the paper; in this case the barbette is circular in section and of about the usual diameter, with gateways cut for the chases of the guns in descending. When it is further recalled that the command of the guns there shown remains the same as for the usual turret guns, that they are not supposed to be raised a deck higher in order to be above the medium caliber guns, but that the latter are placed lower, the difficulty of so disposing them being elsewhere treated, it will be seen that the difference, advanced as to the question of weight, disappears altogether. The conclusion on this subject arrived at in the paper is beyond question.

There is no occasion to take issue with the idea advanced that conditions can be imagined such that, as when a portion of the battery is out of action, it might be disadvantageous to have the disappearing privilege, not caring for it at the time while it entailed inferior protection. It need only be remarked that this observation, founded on a conception of the employment of unperfected mechanism, enters the category of the disadvantages pointed out as incurred by such mechanism, annulling quickly all the advantages sought. On the conception of perfected mechanism, where the gun is below when desired only during its inert period, being raised but a fraction of this time, assuming a gun of large caliber, for the purpose of firing, while thus losing little, if anything, in rapidity of fire, enjoying a mean protection equal to or superior to the uniform protection of a heavy turret, it still possesses a possible recourse to greater security. Indeed, admitting perfected mechanism, the more precious the guns become, the more precious become the advantages pointed out. The supposition of perfected mechanism being made, the conclusions of the paper cannot be avoided.

Among the conclusions in the valuable discussion referred to, special note should be taken of the one that confirms the value of the 8-inch guns by the admission of equality with the 12-inch guns in quality of energy generated, an admission that perhaps could not be allowed under all conditions, though easily granted for a general comparison, in view of the great area of most important armor outclassed by the 8-inch guns. It will be seen, referring to page 612, that though in a single round the 12-inch guns of the Iowa generate 104,000 foot tons, and the 8-inch guns but 64,000 foot tons, yet in a given time, sufficiently long, the total energy of the 8-inch guns will exceed that of the 12-inch guns in the ratio of 16 to 13.

Finally, it should be remarked that where special reply has not been made to divergence in any discussion from the conclusions of the paper, it will be found in each case that opposing positions taken in other discussions form ample reply.

SUGGESTIONS FOR INCREASING THE EFFICIENCY OF OUR NEW SHIPS.

(Discussion continued from No. 75.)

Lieutenant HARRY P. HUSE, U. S. Navy.—Mr. Baxter, in his essay advocating simplicity in the design of men-of-war, has given form to an opinion long held by our sea-going officers. The "box of tricks" has never met with favor among seamen. But the essayist has left one point untouched which opens up almost as wide a field as that covered by his essay, and is closely connected with it. I mean the sacrifice of efficiency for the sake of the beautiful. Throughout the service, the ornamental pilot-houses, chart-houses, skylights, and other structures of the kind are made handsome with panelings and polished woods, but they would furnish great quantities of splinters to be scattered among the neighboring guns' crews. Boiler-iron and cork-paint would be more efficient, but are not used because they would not look as well. The mahogany skylights of the Cincinnati excite the admiration of all visitors, but they add considerably to the weight on the poop and interfere with the efficiency of two of the most important guns of the ship. A handsome booby hatch on the same ship paneled and made of polished mahogany is entirely unnecessary, but is carefully placed between the two after 5-inch R. F. guns so as to interfere with their loading and training.

The desire to make ships resemble yachts has detracted from their efficiency. And what a mistake it is even in striving after the aesthetic! A man-of-war is never so beautiful as when cleared for action, when all unnecessary fittings are removed, and when every effort has been made to make the ship as bare as possible.

Mr. Baxter is right when he says that the comforts of the officers have been increased while those of the men have been lessened. The truth seems to be that when the comfort of the crew conflicts with the efficiency of the ship the crew have suffered; whereas, in the officers' quarters everything has been sacrificed to elegance and to their convenience. A man-of-war is primarily a fighting machine. Consistent with its efficiency in a purely military sense, it should be made as comfortable as possible for those who live on board. Aestheticism should never for one moment be allowed to trench upon either of these attributes.

PROFESSIONAL NOTES.

OFFENSIVE AND DEFENSIVE WEAPONS AT THE BATTLE OF THE YALU.

[DEUTSCHE HEERES ZEITUNG.]

The battle of the Yalu was the most important event in the conflict between China and Japan. It secured to the Japanese Navy the supremacy in the Yellow Sea at the very outset.

This battle is, of course, a very incomplete picture of what would occur in a naval battle in the Mediterranean, for instance, between European fleets. The strength of the Chinese was superior to that of the Japanese; but the condition of the material, absence of rapid-fire guns, and miserable training of the personnel placed the Chinese in an inferior position. Without dealing with questions of naval tactics, we may consider certain phases and results upon which the personnel had but little influence, and arrive at conclusions.

1. THE HULL.—The vital parts suffered comparatively little, but the upper works and military masts were penetrated, and the crews were injured by flying splinters and pieces of the hull as much as by the shell and bullets.

All superstructures increase the number of flying pieces, offer an increased target, and cause the explosion of projectiles which would in their absence have passed over harmlessly. The upper works should, therefore, be reduced to a minimum, consistent with the object of obtaining the necessary accommodation and seaworthiness.

Numerous fires broke out in cabins and in coal-bunkers. Woodwork and upholstery should be avoided. The Japanese officers concluded that all bedding and hammocks should be stowed below. The present means of putting out fires aboard ship are insufficient.

It was further shown that light parts constructed of soft metal suffered least by the passage of projectiles, and admitted of easy subsequent repairs, where the harder metals were shattered or splintered.

2. ARMOR.—Armor played an important rôle; it stopped rapid-fire projectiles. Everything unarmored was penetrated and shattered; but a thin armor along the whole freeboard would certainly have been of greater protection than the armor belt of great thickness. This is more evident even in view of the employment of melinite shell in the future. There were few hits at the water-line. The average hits are very much higher, and the penetration is less in practice than in theory, in consequence of the angle of incidence, which departs considerably from the normal. Armor did not insure success, for the Japanese vessels were much less protected than the Chinese in this regard. It seems evident that the great dead-weight of armor would be more efficient if put into the battery and guns. The hypothesis that a vessel whose dead parts have been destroyed will continue the battle

is illusive. The vessel may float, but may be looked upon as deserted and out of the fight.

The Chinese would have lost fewer ships if a greater number of them had been fitted with transverse bulkheads.

None of the engaging vessels were fitted with nickel steel or Harveyized armor. Coal afforded protection, as on board one of the unarmored Chinese ships a heavy projectile was kept out by the coal.

3. THE RAM. — The ram did not come into play, although several attempts at ramming were made. But the ram is not to be despised on this account, as it may be of the greatest effectiveness against a vessel partly disabled by gun fire or torpedoes; or a vessel, finding its gun fire ineffective, may by a bold attempt at ramming disable or sink a better armed but sluggish opponent.

4. SPEED.—Speed played an important part. Admiral Ito with his fast vessels was enabled to select his fighting distance, and by rapid movements to lessen the chances of being struck by Chinese projectiles. The battle demonstrated that a rapid, well-armed vessel can enter into combat with battle-ships. It has increased the supporters of rapid cruisers carrying heavy batteries.

The Chinese vessels found greater protection in the distance at which Admiral Ito remained than in their armor. But this constant manœuvring at high speed necessitates large coal supply. The necessity of enlarging the radius of action is emphasized.

5. AUXILIARY CRUISERS.—The auxiliary Saikyo was not fitted to take part in battle. She was surrounded and deprived of her rudder, in imminent danger of capture or destruction, so that part of the Japanese fleet had to go to her assistance. Auxiliaries are valuable, but unless they possess high speed and a powerful armament should not be dragged into an action where they are an obstruction rather than of any assistance.

This instance serves as a good example of the degree in which a fleet or squadron may be hampered by a slow vessel.

6. SMALL-ARM FIRE played no part. Gatlings may be useful on certain occasions, but the rifle which requires the detachment of a numerous personnel from other important duties has little effect compared to that of gatlings at all distances.

7. TORPEDOES.—The automobile torpedo played a very insignificant part. Owing to the destructive effect of the artillery fire on the gun-decks, the presence of charged torpedoes in the launching tubes is a constant menace. The Japanese generally left the torpedoes in the torpedo or storerooms. Several Chinese vessels freed themselves by throwing their torpedoes overboard. Under-water tubes do not possess these dangerous features.

The training and elevating gear of the tubes worked badly, which caused some officers to advocate fixed tubes. The Chinese made several attempts to sink Japanese vessels with their torpedoes, but, though launched at distances of only 80 meters, they missed the target. This shows evident ignorance of proper launching, and besides, this distance was too small for torpedoes which are forced to make a large initial dive owing to height of tubes above water. Had the Japanese fleet been aided by its torpedo-boats the disaster to the Chinese fleet would no doubt have been even greater.

8. ARTILLERY.—The battle was decided essentially by the gun. The heaviest guns of the Chinese were 30½-cm. Krupp guns, as opposed

to 32-cm. Canet guns of 40 calibers length of the Japanese. A shell from one of the latter guns struck a Chinese vessel, partly penetrating, tearing away an armored bulkhead and sinking the vessel. The barbette turret of the Matsushima was partly destroyed by the 30½-cm. shell, and the 32-cm. gun could fire only four shots. A 30½-cm. shell exploded on the deck of the Matsushima, causing an explosion of stored shell and killing and wounding about 80 men. These heavy guns proved more effective than those of smaller caliber, especially as the armor in question was only of medium thickness; and it cannot be denied that, leaving out the question of penetration of heavy armor, large shell traveling with high velocities destroy everything in their paths and effect terrible damage. It was demonstrated that one lucky hit with a shell of large caliber will sink a ship.

It was further proved that simplicity in the service of heavy guns is an important factor. The loading is much too slow. The hydraulic apparatus worked well at the beginning, but fragments from exploding shells soon shattered pipes, destroyed the hoisting apparatus or disabled the training gear, necessitating service by hand. This is a new argument in support of the claims of advocates of balanced turrets and mechanical hand gear in place of complicated system of pipes and other contrivances for service of the guns. Electric appliances are just as vulnerable as the hydraulic gear, but much simpler. Furthermore, it was shown in an official report that the hydraulic system suffered in consequence of the low temperature, so that fires had to be kept in the turrets and near the pipes to prevent freezing up. It is believed that electric motors would give less trouble.

The rapid-fire guns decided the battle. They permitted the Japanese to penetrate or destroy the dead works of the Chinese vessels from the very beginning. The Japanese possessed manifest superiority in this regard over the Chinese, who possessed Krupp guns with slow breech mechanism.

The firing was wild, and waste of ammunition considerable. It was noticed that many of the Japanese 12-cm. shell failed to penetrate the Chinese armor. At the fighting range they seemed to possess too little energy. The muzzle velocities were less than 700 meters; had these velocities been greater the results would have been very different.

ARTILLERY IN THE BATTLE OF THE YALU.

[Mittheilungen aus dem Gebiete des Seewesens.]

The Japanese attribute their victory to their rapid-fire guns. They manœuvred in such a manner as to fight at 2000 meters, forcing an artillery duel in which, with their rapid-fire batteries and better trained crews, they were enabled to frequently set fire to the Chinese vessels. The fires started on board the Japanese ships were soon put out with better facilities and superior organization. In the Chinese vessels the flames were caused by presence of hammocks, sails, wood and other inflammable objects. Fire during action is demoralizing. It would be interesting to know whether the decks were wetted down before the action. The Chinese left their boats in port before the action. This may have been a good plan, for even though boats be not struck by the enemy's projectiles, they are rendered unserviceable by the concussion of one's own battery.

CONCENTRATED FIRE.—In days of sailing ships it was possible to cut off a part of the enemy's fleet and to concentrate fire upon this part with the object of destruction before aid could come from the remainder of the fleet. With steamships this is impracticable, but why should the fire of all guns of a fleet be not concentrated upon a single vessel of the enemy? A disabled vessel will hamper the enemy's movements, as his manœuvres will have to be altered in giving protection; furthermore, it would seem productive of better results than if each vessel fires without distinction upon the vessel nearest to it at the time.

BROADSIDE VERSUS FORE AND AFT FIRE.

A study of this latest sea fight will naturally lead to a comparison of broadside and fore and aft fire. Is there not a sacrifice of the former in favor of the latter in modern war vessels? A vessel should be able, of course, to sweep the horizon with its guns; yet it is the broadside which will decide the battle, especially in fleet actions. A vessel with its keel-line towards the enemy affords a better target than when its broadside is presented, for the difficulty in hitting lies in the proper elevation, and a projectile which just clears a ship in the latter position might hit if the elongated target of the former position were presented. An ordinary vessel presents in this position a dangerous space of about 300 feet, while the beam of say 36 feet is not a difficult target for a good marksman. In the past everything tended to avoiding this position. Our forefathers had more war experiences than we, and why should we depart from their rules, and by fitting our ships for fore and aft fire expose them to the raking fire which will prove just as disastrous in the modern cruiser as in the old frigate? In the sea fights of the French Revolution the French frequently used with effect the line ahead to receive the attack of an attacking fleet advancing in line abreast. The tactics of Rodney, St. Vincent and Nelson to concentrate their fleets upon a portion of the enemy's fleet counteracted this formation of the French. In our days such concentrated attacks can be met or parried, and the action will soon resolve itself into an exchange of broadside fire, whether in fleet or single action.

The importance of secondary batteries was demonstrated in case of the Matsushima, which was able to continue in the action even after her heavy gun was disabled. Another lesson taught is the necessity of providing for service by hand of heavy guns, in case of the destruction of the hydraulic or mechanical gear.

The importance of subcaliber practice was shown in the superior marksmanship of the Japanese.

The frequency of fires on board the ships testifies to the effectiveness of the modern fuzes. At about the same time an English man-of-war was able to test the fuzes during the bombardment of an African village. They were found, perhaps, too sensitive, as contact of the shell with trees or limbs frequently exploded the Hotchkiss 47-mm. base fuze. Cordite was used on board the Yoshino and gave admirable results, having apparently suffered no deterioration from change of climate.

The Japanese possessed superior arrangements for supply of ammunition. The empty shells were thrown down the open hatches after fire, and in spite of this rough treatment most of the cases were in a condition to be reloaded after the battle.

The utility of gun shields was rendered doubtful by the battle. Though affording protection at short ranges against small-arm fire, yet at long ranges the thickness is not sufficient to keep out large projectiles, and will invariably explode shell striking them. If not properly secured, the shield when struck and carried away also disables the gun.

H. G. D.

DETERMINATION OF THE FIGHTING VALUE OF A VESSEL.

(Method of Captain Bettolo of the Italian Navy.)

[Mittheilungen aus dem Gebiete des Seewesens.]

To compare the fighting efficiencies of different vessels, an ideal ship embodying to the highest degree the defensive and offensive strength is taken as a unit or type, and the following formula is used:

$$B = K.f(S)\{f(q) + f(d) + f(v)\} \; . \; . \; . \; . \; . \; . \quad (1)$$

In this formula certain relations exist between the functions S of displacement, q of offensive power, d of defensive power, v of speed.

If Δ represents the displacement, Q the offensive power, D the defensive power, and V the speed of the ideal ship used as unit; then

$$f(S) = \frac{S}{\Delta}, \; f(q) = \frac{q}{Q}, \; f(d) = \frac{d}{D}, \; f(v) = \frac{v}{V},$$

and formula (1) becomes $B = K\frac{S}{\Delta}\left\{\frac{q}{Q} + \frac{d}{D} + \frac{v}{V}\right\}$ . . . . . . (2)

The coefficient K expresses the degree in which the vessel under question possesses the offensive and defensive qualities referred to those of the most modern types of vessels.

In vessels recently launched K has the value 1, in older vessels K is a fraction. The following values have been assigned to K:

For vessels launched since 1886, $K = 1.0$
" " " between 1881 and 1885, $K = .9$
" " " " 1876 and 1880, $K = .8$
" " " " 1871 and 1875, $K = .7$
" " " " 1866 and 1870, $K = .6$
" " " prior to 1865 $K = .5$

In wooden ships K is to be further multiplied by ⅔.

First a battle-ship, next a cruiser, is brought under consideration.

Displacement.—The greatest displacement being 15,000 tons, $\Delta = 15000$ in equation (2).

Offensive powers.—The offensive strength is based upon the total energy developed from the armament, and proportional also to the number of torpedo tubes. If E represent the total energy on the unit ship, e that of the vessel considered, and N the number of launching tubes of the former, n that of the latter, we can substitute $(\frac{e}{E} + \frac{n}{N})$ for $\frac{q}{Q}$ in equation (2). In determining the energy of the guns, regard has been taken of the rapidity of fire, supposing that similar conditions obtain in all nations.

Assume $E = 100000$ meter kilograms (this value is the sum of the energies imparted by five 14″.56 Canet guns to their projectiles).

In order to take into account the greater destructive effects of the heavier calibers, the following percentages are assumed, which enter into the above solution:

With guns of	37 cm. (14″.6) to 45 cm. (17″.7)	100%
"	32 cm. (12″.6) and 34 cm. (13″.4)	90%
"	25 cm. (9″.8) and 27 cm. (10″.6)	80%
"	19 cm. (7″.5) and 20 cm. (7″.87)	70%
"	14 cm. (5″.5) to 17 cm. (6″.7)	60%
"	12 cm. (4″.7) and 10 cm. (3″.9)	40%

We assume six torpedo tubes on our ideal ship. If we followed the above rule we should find $\frac{n}{6}$ as a factor to express the power of the ship in question. But as an increase of n would increase the value of $\frac{q}{Q}$ to a greater extent than the addition of a corresponding number of launching tubes would increase the offensive power of a heavily armed battle-ship, the expression $\frac{\sqrt[3]{n}}{\sqrt[3]{6}}$ is supposed to be nearer correct. The cube root is introduced because the total number of torpedoes and their explosive charges is proportional to n, whereas the submarine destruction possible from a ship is proportional to the cube root of the total weight of its explosive charges.

$$\therefore \frac{q}{Q} = \frac{e}{1000} + \frac{\sqrt[3]{n}}{\sqrt[3]{6}}.$$

Defensive power.—In considering this factor, only vertical armor is taken into account, as the other protective means, such as protective deck, water-tight compartments, etc., enter into the coefficient K, which indicates to what extent certain modern protective features obtain on board the vessel under consideration.

The efficiency of vertical armor depends upon two factors: upon its thickness, and upon the ratio of its area to that of the ship's side.

Let $L =$ the ratio of length of side armor to length of the ship,

$H =$ height of vertical armor, in meters,

$T =$ thickness of armor in centimeters,

$\therefore d = f(L, H, T)$.

In considering the thickness of armor plates as applied in modern vessels, and their behavior when struck by projectiles, the following principles are taken into account:

1. That plates of 10 to 15 centimeters (3.94 to 5.91 inches) thickness keep out small-calibered projectiles, and weaken the explosive effects of large caliber projectiles by causing their explosion outside the ship before they have penetrated.

2. That although the resistance of heavy plates against penetration depends in the first place upon the thickness, yet it is not directly proportional to this thickness, varying with a quantity intermediate between the square and first power of the thickness, the exponent of which quantity decreases as the thickness increases. From consideration of ballistic tests, these relations may be expressed by considering

thicknesses up to 10 centimeters of a plate as playing a greater part in the resistance than the remaining thickness of metal. This is shown in the expression $10^2 + (T - 10)$. We therefore have

$$f(L, H, T) = L.\ H.\ [10^2 + (T - 10)].$$

Denoting the corresponding elements in the vessel in question by l, h and t, the defensive power may be expressed by

$$\frac{d}{D} = \frac{l.\ h.\ [100 + (t - 10)]}{L.\ H.\ [100 + (T - 10)]}.$$

If in the vessel selected as type or unit of measure $L = 1$, $H = 4$ meters, $T = 55$ centimeters, the above formula becomes

$$\frac{d}{D} = \frac{l.\ h.\ [100 + (t - 10)]}{580}.$$

Speed.—A speed of 20 knots is assumed as a possible maximum in large battle-ships.

Formula (2) now takes the form

$$B = K \frac{S}{15000} \left\{ \frac{e}{1000} + \frac{\sqrt[3]{n}}{\sqrt[3]{6}} + \frac{l.\ h.\ [100 + (t - 10)]}{580} + \frac{V}{20} \right\}.$$

As there are four terms in summation in the parenthesis in the above equation, the value of each of which cannot exceed unity, and as B can have no greater value than 1, we may introduce 4 as a divisor; obtaining finally

$$B = \frac{K}{4} \frac{S}{15000} \left\{ \frac{e}{1000} + \frac{\sqrt[3]{n}}{\sqrt[3]{6}} + \frac{l.\ h.\ [100 + (t - 10)]}{580} + \frac{V}{20} \right\}.$$

This is for battle-ships. For cruisers the formula is slightly changed. It is to be remarked that torpedoes play a more important part in cruisers than in battle-ships, making it necessary to use n instead of $\sqrt[3]{n}$ in the above formula. In an armored cruiser taken as unit of measure for comparisons of other types of this class of vessels, we may assume $\Delta = 8000$ t., $E = 30000$ mkg., $N = 8$, $T = 20$ centimeters, $L = 1$, $H = 4$ meters, $V = 25$ knots. Whence the formula for cruisers is

$$B = \frac{K}{4} \frac{S}{8000} \left\{ \frac{e}{300} + \frac{n}{8} + \frac{l.\ h.\ [100 + (t - 10)]}{440} + \frac{V}{25} \right\}.$$

H. G. D.

AN EXPERIMENTAL TEST OF THE ARMORED SIDE OF U. S. S. IOWA.

[IRON AGE.*]

For the purpose of this test a target was constructed of the length of one armor plate, consisting of all the framing which exists in the actual ship in rear of such plate, to which was attached in the usual manner the actual armor plate selected for the ballistic test of a group of this armor.

The framing extended the height of the armor plate, and in an inboard

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* Abstract of a paper read by Albert W. Stahl, Naval Constructor, U. S. N., at the convention of the Society of Naval Architects and Marine Engineers.

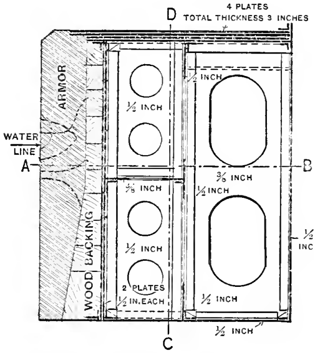


FIG. 1.—*Transverse Section of Target.*

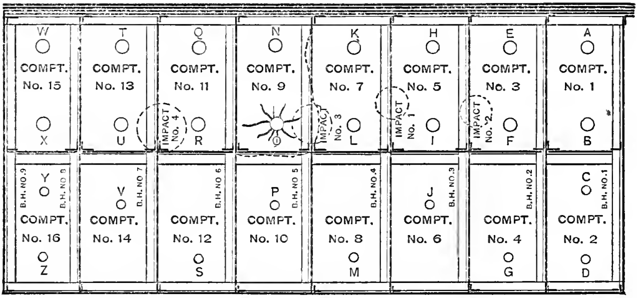


FIG. 2.—*Section on Line C D of Fig.* 1.

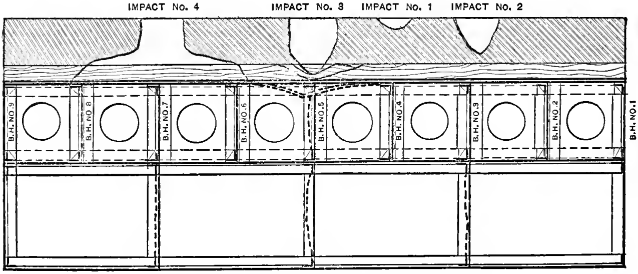


FIG. 3.—*Section on Line A B of Fig.* 1.

direction included the first longitudinal bulkhead within the armor. The total structure was thus 16 feet long over all, 6½ feet wide and 7½ feet high. While such an isolated portion of the ship's side cannot, of course, offer absolutely the same resistance as the corresponding part of the ship itself, thoroughly connected as the latter is with the rest of the hull, yet it was deemed to be a sufficiently fair test to warrant us in accepting the results of the same as representing, with a considerable degree of accuracy, what would happen in the ship under similar circumstances.

Figs. 1, 2 and 3 show the target used in the test. Fig. 1 is a transverse section; to the left is the armor, 14 inches thick in its parallel upper portion, and tapering down to 7 inches at the bottom. Between the armor and the framing proper is the wood backing, 5 inches thick in its upper portion, and tapering to suit the shape of the armor in the lower portion.

Immediately within the wood backing are two steel backing plates, each ½ inch thick; these plates in the Iowa are really ⅝ inch thick, but the lesser thickness was used in the target both as a matter of convenience and to bring it into accord with the ½ inch thickness adopted in the design of the two recently authorized battle-ships, Nos. 5 and 6. The rest of the framing consisted of transverse vertical bulkheads ½ inch thick and 2 feet apart, the alternate ones being extended to the rear with a thickness of ⅜ inch and connected to a main longitudinal bulkhead of the ship, while the others were simply stiffened at the rear with a flange consisting of two angle irons riveted back to back. The longitudinal members of this cellular framing consisted of the armored deck above, an ordinary deck below, and a horizontal plate at about mid-height, together with 3 vertical stiffening plates at top, at bottom, and at mid-height respectively. The various portions were thoroughly united by angles and butt straps. Fig. 2 shows also the number and location of armor bolts, of which the upper ones were 2.8 inches diameter, while the lower ones were 2.4 inches in diameter.

This target was secured to a heavy supporting structure so arranged as to support the target at top and bottom only, representing the support due to the decks of the vessel. It consisted of 8 vertical timbers of oak, butting at the bottom against horizontal timbers, and near the top against inclined braces, all these timbers being about 15 inches square. The incline braces were secured to the verticals by heavy angle irons, and by bolts to the horizontals below them. Behind the junction of the horizontal and inclined timbers were placed a set of nearly horizontal timbers 16x9 inches, which in turn rested against piles 20 inches square driven 5 feet into the ground. Running to the front from the feet of the verticals were other horizontal timbers, 15 inches square, the front ends of which were bolted down to doubled cross timbers, 12 inches square, imbedded in the ground. This extremely strong structure was then filled in with sand, so as to render it as rigid and unyielding as possible; and finally the target was secured in the front angle of the same by about 100 1½-inch bolts, being separated from the main structure by cross timbers at top and bottom, the object of the latter being to confine the resistance to the two deck levels, as above explained.

Four shots were fired at this target—two 10-inch, one 12-inch, and one 13-inch—the first two forming the regular acceptance test of the armor plate, and the last two being specially designed to test the strength of the framing. The angle of impact was practically normal in all cases.

The first shot was fired from a 10-inch breech-loading rifle. The projectile was a Carpenter shell (weight about 500 pounds), hardened to 2.5 inches below bourrelet, with a charge of 140 pounds of powder. The distance from the gun to the armor was 388 feet; the striking velocity of the projectile was 1432 feet per second. This gave a total striking energy of 7622 foot tons, or 286 foot tons per ton of armor, being 1.29 times the energy required to just penetrate a wrought iron plate of same thickness. The shell struck the plate 71 inches from left edge, 27 inches from top bevel, immediately in front of bulkhead No. 4, between armor bolts K, H, L and I, and 8 inches above the center line of second row of armor bolts. The projectile broke up, the head to 6 inches from point remaining welded in the armor, and the balance of the projectile being broken into many small pieces, which were scattered to great distances.

The armor was penetrated 3.75 inches, as shown in Fig. 3, the diameter of shell metal in impact being 10 inches. The diameter of splash was 14.5 inches. There was no front bulge or fringe; back bulge not visible, but probably very slight. No cracks whatever were developed in the armor, and the wood backing seemed uninjured.

The framing suffered practically no damage, only one rivet in the angle in compartment No. 11 being sheared. All the 1.25-inch tap bolts binding the armor deck to top of armor were sheared, due to the fact that in the target structure there was an imperfect fit between the armor and the plating representing the armor deck, thus permitting the former to move slightly relatively to the latter. This has been obviated entirely in the actual structure of the ship.

The second shot was fired from the same gun, being a similar shell, but with a charge of 217.2 lbs., giving a striking velocity of 1856 feet per second. The corresponding total striking energy was 11,954 foot tons, or 448.6 foot tons per ton of armor, being 2.3 times the energy just necessary to penetrate a wrought iron plate of same thickness. The shell struck the armor 45 inches from left edge, 29.5 inches from top bevel, and 25 inches from impact No. 1, in front of lower part of compartment No. 3, just to the left of bulkhead No. 3, and 6.5 inches above center line of second row of armor bolts, near bolt F.

The projectile broke up at the bourrelet, the head remaining in the armor, and pieces of the body and base being scattered around in front of the target. The armor was penetrated 11 inches, the diameter of shot hole being 13 inches. The armor splashed and flaked 17 inches by 18 inches. There was a front bulge ½ inch high and 17 inches diameter. The fringe was very slight, with fine cracks in it. The back bulge was not at this time determined, but the plate in rear of armor and backing was found to have bulged slightly, though it was not cracked. The backing was in good condition, except slight splits at edges of one of the timbers. Armor bolt F was driven to the rear, the end which was screwed into the armor having the threads stripped on side nearest projectile. No damage whatever was inflicted on the framing; though, owing to a slight deformation of the armor, some of the armor bolt fittings became somewhat slack.

The third shot was fired from a 12-inch breech-loading rifle, the projectile being a Wheeler-Sterling armor-piercing shell (weight about 850 pounds), hardened to 2 inches below bourrelet, with a powder charge of 400.6 pounds. The striking velocity was 1800 feet per second, giving a striking energy of 19,114 foot tons, or 717.23 foot tons per ton of armor plate, being 2.69 times the energy just necessary to penetrate a wrought-iron plate of same thickness.

The projectile struck the armor 95 inches from right edge, 27.5 inches from impact No. 1, and 33 inches from the top bevel, directly in front of bulkhead No. 5, the point penetrating 3.75 inches through the plate. The shell broke up below bourrelet, at about 15 to 18 inches from base, set up and cracked longitudinally from base to bourrelet, the two portions of body and base falling in front of target. The head of shell remained in the shot hole, the point and 3 inches of ogive being detached and carrying the back bulge into backing in rear of armor.

The diameter of the shot hole was 13.75 inches, and the diameter of splash in flaking was 20 inches. There was a front bulge ½ inch high and 2 feet in diameter; fringe slight and cracked around shot hole. A portion of the armor on left side of shot hole was nearly detached. The plate was through cracked from top to bottom, through the impact, and was also partially cracked from this impact to impact No. 1 and to the left of same impact to impact No. 2. The ends of the armor plate moved 1.25 inches to the front and away from the framing. There was no movement in the framing itself. In Figs. 2 and 3 is shown the damage inflicted on the framing by this shot.

The framing of bulkhead No. 5 between compartments Nos. 7 and 9 was buckled 3 inches to the right at the top, and a similar amount to the left at the bottom. The connecting angle iron in lower right-hand corner of compartment No. 7 was bent to an angle of 90 degrees at a point 2 inches from the plating behind armor, but none of the rivets in the angle iron were sheared. The plating behind armor and backing in compartment No. 7 and in the vicinity of impact No. 3 was driven to the rear 2 inches; while in the rear of the impact it was locally bulged 5 inches, carrying with it armor bolt O, which was sheared off by the blow. The fractured armor bolt having been knocked out with a sledge hammer, showed the wood backing compressed to 1 inch on the right side of this bolt hole, while it was of normal thickness on the left. The rear portion of bulkhead No. 5 buckled 2.5 inches at the middle and somewhat less at top and bottom. The rear portion of bulkhead No. 7 buckled ¾ inch and the rear portion of bulkhead No. 3 buckled 1 inch near bottom. The middle horizontal plate between bulkheads Nos. 5 and 6 was buckled ½ inch. Four flush rivets in the ½-inch backing plates, together with the heads of three rivets in one of the angle irons, were sheared off. No other rivets were broken.

Although this projectile actually penetrated the armor, the damage to the framing, as above specified in detail, was trivial; and, so far as the framing was concerned, no repairs whatever would have been needed to enable it just as efficiently to withstand a second blow of this energy had the armor plate not been cracked through. The framing thus fulfilled, and even exceeded, the first condition laid down—that it must suffer no material damage from any shot not fully penetrating the armor.

The fourth shot was fired from a 13-inch breech-loading rifle at a distance of 378 feet, the projectile being a Wheeler-Sterling shell (weight about 1100 lbs.), hardened to a rear part of bourrelet, with a powder charge of 484.2 pounds. The striking velocity was 1800 feet per second, giving a striking energy of 24,763 foot tons, or 1903 foot tons per ton of armor (considering, in this case, only the detached portion of armor plate struck by this shot), being 3.46 times the energy just necessary to penetrate a wrought-iron plate of the same thickness. The projectile struck the armor plate 39 inches from extreme top of plate, 8.5 inches above bevel line, and 45 inches to right of impact No. 3 and 48 inches from right edge.

The projectile penetrated armor and framing completely, being found 12 feet in the sand butt in rear of target. The shell was found to have been set up 3 inches in length and increased in diameter 0.55 inch at bourrelet. The diameter of shot hole in armor was 14 inches; interior smooth. There was no splash; the mean diameter of flaking was 27 inches. The front bulge was mostly flaked away, that remaining on the armor being ½ inch high and 27 inches diameter. There was a back bulge, 4 inches high and about 45 inches diameter, broken out all around, two pieces of from 500 to 600 pounds each being carried to the rear and lodging in the framing, while other smaller pieces were carried right through with the shell. The armor plate was cracked through from this impact in an almost horizontal line to impact No. 3, also through cracked from top of impact diagonally to top of plate, and through cracked from left-hand side of impact vertically down to bottom of plate.

The experiment concluding with this shot, both armor and wood backing were removed from the framing, for the purpose of further examination. The backing was badly splintered and carried away in rear of this impact. The wood backing was next removed from the armor. None of the armor bolts, except those in the line of impact, were injured.

A detailed examination of the framing after the armor and backing had been removed showed the following effect of all four shots:

Measured at the center line, the face of the structure as a whole was bulged inward away from the straight line connecting the two ends about 2 inches. There was no damage to the plating caused by the two 10-inch shots except a bulge 12 inches diameter and 2 inches high in rear of impact No. 2. Opposite impact No. 3, the two ½-inch plates behind the wood backing were indented 5 inches by the back bulge of the armor, this indentation extending over an area about 3 feet in diameter. Of these two plates, the one next to the backing contained a continuous crack in the indented surface extending from the bolt hole L to bolt hole O, thence upward and to the left 18 inches, almost following a line where the back bulge was broken out. In rear of impact No. 4 these two plates were broken out, making a hole 44.5 inches by 51.5 inches, the ragged points of the metal being folded inward at a sharp angle on the left side, the plating being cracked at the angle. This plating, the vertical bulkhead No. 7, and the rear bulkhead of target structure in rear of this impact were turned, twisted, bent and fluted, the plates being twisted into all sorts of shapes, exhibiting the fine quality of the metal. The holes in the bulkheads were very much larger than the diameter of the shell. Bulkhead No. 7 was cut off 36 inches from bottom and about 12 inches from top. The plates forming the rear part of framing bulged out 19 inches to the rear and were cracked through, the plate being split and bulged over an area of 42 inches wide by 105 inches long, the rivets binding these plates together being sheared over a length of 106 inches.

The upper portion of bulkhead No. 8 was bent to the right 3 inches, and slightly warped; the upper portion of bulkhead No. 6 was twisted to the left about 5 inches, and badly buckled. The intermediate vertical stiffening plate, ½ inch thick and 12 inches wide, was broken through in rear of impact, and carried away between bulkheads Nos. 5 and 8. The similar upper stiffening plate was bent to the rear about 7 inches between bulkheads Nos. 6 and 8. The deck beam at bulkhead No. 7 was uninjured. Bulkhead No. 5 was slightly buckled, the injury to this bulkhead by impact No. 3 having been slightly increased by this impact. Armor bolt U in rear of impact No. 4 fell out from back bulge, broke through and dropped to the bottom of compartment No. 14, the bolt being uninjured except that the portion which screwed into the armor was slightly bent.

Armor bolts V, S, Q and T were in place and practically uninjured. Armor bolt R was sheared at rear surface of plate and thrown to the rear into compartment No. 12. All the timbers of the backing were loosened up and moved away from the plate, the calking being loosened around the armor bolts. Eight of the backing timbers were crushed and broken in two in rear of back bulge of impact No. 4 and six of them in rear of back bulge of impact No. 3. The plate and target structure moved to rear 2 inches. None of the fastenings securing the plate and structure to the wooden target structure were injured. One of the vertical timbers in rear of target was cut in two by the projectile, but remained in place, its inclined brace directly in rear being carried away for a length of 48 inches, the lower part of it remaining in place.

This detailed statement of the injuries inflicted, together with the engravings, shows clearly the extent of the damage. While the injury was very serious behind impact No. 4, where the shell penetrated completely, the important point to note is that it was entirely local, plates and angles a short distance on either side of this impact being practically uninjured; thus satisfying the second condition above stated as requisite. The framing thus, on the whole, showed the effectiveness of its design and clearly demonstrated its complete efficiency for its intended purpose. This test is the most important one that has ever been made, at least in our service, to settle the much discussed question of strength of framing; and it is naturally a great source of satisfaction to all interested in naval affairs to feel that what has been done in the design and construction of such framing in our various ships has been well done, and that no apprehension need be felt on that score.

A POLARIZING PHOTO-CHRONOGRAPH.

In the July number of the Journal of the United States Artillery appears a very interesting and instructive article entitled "Experiments with a New Polarizing Photo-Chronograph, Applied to the Measurement of the Velocity of Projectiles," by Dr. Albert Cushing

Crehore, Assistant Professor of Physics, Dartmouth College, and Dr. George Owen Squier, First Lieutenant, Third Artillery, U. S. A. We had intended publishing this article in full, but find our space so limited that we have been compelled to cut out some of the details, and accordingly we publish the following (mostly an extract), which is all that is necessary to a general understanding of the subject.

The nature of this instrument is such that it is admirably adapted for recording the passage of the projectile at a number of points of its trajectory, which points of observation may be as near together as is desirable. For this reason it was made an object to study the law of variation of the velocity of the projectile near the muzzle of the gun. Its superiority over other known methods of measuring velocities is due to the fact that in recording, no ponderable matter is required to be moved, as is the case with all other instruments for this purpose.

The desirable and possibly essential features of a good chronograph may be classed as follows: There must be some agent in the first place which can transmit, from the phenomenon to be recorded wherever it may be located, the occurrence of the event to a place where it can be permanently made a matter of record. In the second place the agent which is to receive the record must include with it some accurate means of measuring time. For brevity let us designate these two parts of any chronograph by the terms "transmitter" and "receiver." The transmitter will then include all those parts of any chronograph which are instrumental in conveying the occurrence of the event from the place where it happens to the agent which finally receives the record. The receiver includes all those parts that are essential in receiving the record, together with an accurate means of measuring time.

THE TRANSMITTER.

In the path of the beam of white light admitted through an aperture is placed a Nicol prism (any other means of obtaining polarized light may be employed) in order to obtain a beam of plane polarized light. This prism is made of two crystals of Iceland spar, which are cemented together by Canada balsam in such a way as to obtain only a single beam of polarized light. The crystal is a doubly refracting medium, that is, a light beam entering it is in general divided into two separate beams which are polarized and have different directions. One of these beams in the Nicol prism is disposed of by total reflection from the surface of separation where the Canada balsam is located, and the other emerges a completely polarized beam ready for use. Each beam has only one component of the vibration of the original light. One beam has all the up and down components, while the other has all the right and left components. As the wave advances, all the motion will thus be confined to a single plane containing the ray. This is the plane of polarization.

Suppose that a second Nicol prism exactly like the first is now placed in the path of the polarized beam. If then the second prism called the "analyzer" is set so that its plane is just perpendicular to that of the first prism called the "polarizer," all the vibrations not sorted out by the polarizer will be by the analyzer. In this position, the planes being just perpendicular to each other, the prisms are said to be "crossed," and an observer looking through the analyzer finds the light totally extinguished as though a shutter interrupted the beam. By turning the analyzer ever so little from the crossed position, light passes through it, and its intensity increases until the planes of the prisms are parallel when it again diminishes; and if one of the prisms is rotated, there will be darkness twice every revolution.

In order to accomplish the same end that is obtained by rotating the analyzer without actually doing so, the following means is adopted: Between the polarizer and analyzer is placed a transparent medium which can rotate or turn the plane of polarization of the light to another place subject to the control of an electric current without moving any *material thing.* The medium used in these experiments was liquid carbon bisulphide contained in a glass tube with plane glass ends. There are many other substances which will answer the purpose, some better than others. This was selected because it is very clear and colorless, and possesses the necessary rotatory property to a considerable extent. It only possesses this property, however, when situated in a magnetic field of force. The rotatory power, that is, the angle of change of the plane of polarization, is proportional to the intensity of this magnetic field.

To produce a magnetic field in the carbon bisulphide, a coil of wire is wound around the glass tube and an electric current passed through the coil. When the current ceases the carbon bisulphide instantly loses its rotatory power. The operation is as follows: First the polarizer and analyzer are permanently set in the crossed position, so that no light emerges from the analyzer. A current is now sent through the coil on the tube. The plane of polarization is immediately rotated. This is equivalent to rotating the polarizer through a certain angle, and hence light now emerges from the analyzer. Break the current, the medium loses its rotatory power and there is again complete darkness. This arrangement makes an effectual shutter for the beam without moving any mass of matter.

The tube was originally an ordinary chemical laboratory glass condenser tube of 3 cm. internal diameter and 45 cm. long, provided with ground ends upon which plane glass was fitted. Two smaller tubes, projecting from the side of the larger tube near either end, were placed in an upright position so that, when the tube was filled with liquid carbon bisulphide, any bubbles of air which might exist in the liquid would collect in the smaller tubes.

It was found, after trials with a number of substances, that ordinary cane sugar, when melted to a candied condition, would make an impervious cement. The tube was wound with a No. 18 single covered magnet-wire in four equal separate sections along its length.

Resistance of 4 coils in series..................	13.76 ohms.
Resistance of each coil	3.44 ohms.
Resistance of 4 coils in parallel	0.86 ohm.
Total number of turns on tube	2900 about.
Number of turns on each section	725.

The four coils were usually connected in parallel in these experiments, with the object of reducing the inductance of the line, the inductance of the tube itself being reduced sixteen-fold by this arrangement. Since a given strength of magnetic field had to be attained, the line current was therefore larger than it would have been with the coils in series. The current which was ordinarily used was about 17 amperes.

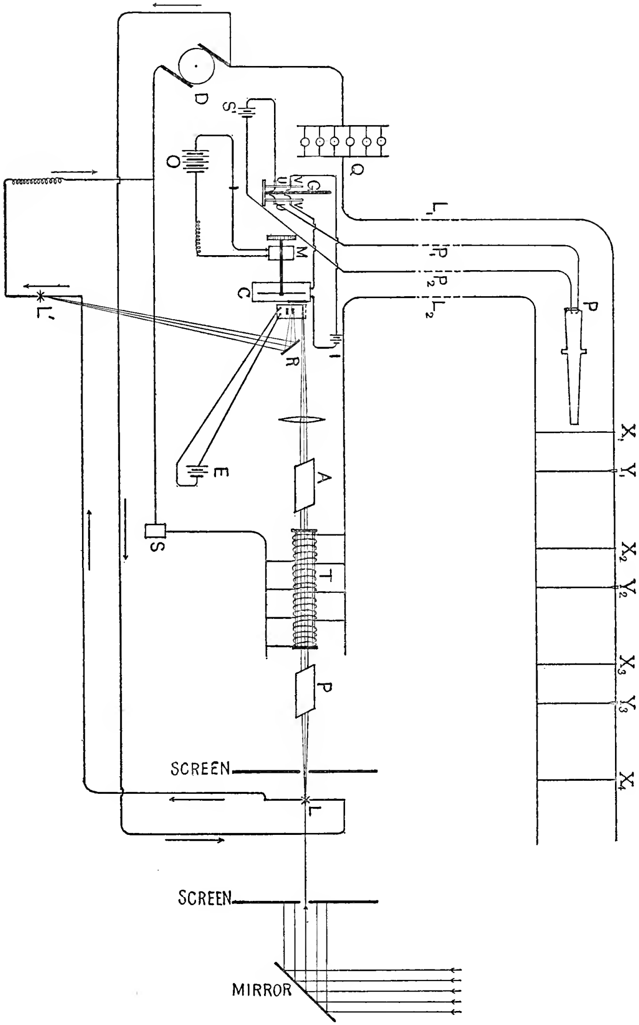
The operation of the transmitter is as follows: When no current is flowing in the circuit, the polarizer and analyzer are permanently set in the "crossed" position for darkness, and then just before firing, the switch S is closed and the current flows through the circuit. This permits light to pass through the analyzer as long as the current is maintained. When the projectile arrives at the muzzle of the gun, the wires of the screen X_1 are broken and the current is completely interrupted. The disappearance of the light through the analyzer is simultaneous with the interruption of the current. When the projectile arrives at the device Y_1 it pulls out an insulating plug and re-establishes the current through X_2. Simultaneously with this, light is admitted through the analyzer, again to be interrupted when the projectile reaches the second screen X_2, and so on. The light through the analyzer is thus intermittent, the transition from light to darkness being so instantaneous as to produce a sharp, well-defined record on the photographic plate of the receiver.

THE RECEIVER.

The receiver is that part of the chronograph which is susceptible of receiving the continuous record from the transmitter, and it also includes that part of the instrument which measures time. It consisted of a circular photographic plate upon a horizontal shaft in a dark box. An approximately uniform rotation was given to it by means of an electric motor, whose armature was coupled directly to the shaft. In order to accurately determine the angular velocity of the plate, whenever it is exposed, a tuning fork is placed so that the shadow of one prong is projected sharply upon it by means of a parallel beam of light from an intense source. The light from the transmitter, as well as the light from the tuning fork, is admitted to the plate through a narrow horizontal slit. When the plate is in rotation, and the tuning fork is vibrating, the shadow of the edge of the fork describes a sinusoidal line around the plate. From a knowledge of the angle on the plate which a certain number of these waves subtend, and the time of vibration of the fork, the angular velocity of the plate at once becomes known.

THE GRAVITY SWITCH.

It was found necessary in the course of experiment to have an accurate means of exposing the camera at just the proper time in relation to the firing of the gun. A gravity form of switch was constructed with this object in view. It consisted of a wooden base with an upright brass rod in its center. On either side of this rod were two wooden uprights carrying the connectors VV and UU. To these connectors were attached wire springs bent inward toward the brass rod. The weight was a cylindrical piece of brass four inches long, with a hole drilled through it lengthwise so as to permit it to slide freely upon the brass rod. The gun was fired by dropping this weight down the rod. When the weight arrived at the springs connected with VV, the electrical circuit was completed through VV, which operated the camera-slide, and upon arriving at the springs connected with UU the primer circuit was completed and the gun was fired. The interval of time between making the camera circuit and making the primer circuit can thus be varied within certain limits, by dropping the weight from different heights. The curve of calibration of this switch was constructed, which gives this interval of time for any height from which the weight was dropped.



Complete Arrangement of Electrical Circuits.

CIRCUITS.

The complete arrangement of the electrical circuits used with the different pieces of apparatus is shown in the diagram, in which *D* is the dynamo, *T* the transmitter tube, *S* a switch which completed the circuit of the transmitter just a moment before firing the gun to prevent heating the coils, L_1 L_2 the line wires leading to the proving ground; *Q* a bank of resistance lamps; $X_1X_2X_3$ etc., the screen wires shunted across between the line wires; $Y_1Y_2Y_3$ etc., the devices for restoring the current successively between the screens; and *L* and *L′* two 50-volt arc lamps in series which for convenience were lighted by the same dynamo. The electrical tuning fork is controlled by the cells *E*; *M* is the motor for running the camera plate; and at *O* are represented four storage cells for energizing the same. *G* is the gravity-switch for exposing the camera and firing the gun, and *C* the camera whose slide is operated electrically by the cells *I* from the gravity-switch at *VV*. The firing circuit contains the electric primer *P* at the gun, the line wires P_1P_2, the dry cells *S′*, and the gravity-switch terminals *UU*.

The principal ballistic result obtained from these experiments may be said to be the locating of a maximum point in the velocity curve outside of the gun. This maximum point is, in the case of the gun and conditions of loading described, at six or seven feet from the muzzle of the gun—certainly more than five feet and less than ten—or about 25 calibers in front of the muzzle.

A few preliminary experiments were tried with a view of determining the value of this instrument for the measurement of velocities inside the bore, but any mention of them is withheld until further experiments can be made.

The preceding is in nearly the words of the authors, but is much condensed. In connection with this instrument we would say that extension of its use into ordinary practice seems to lie in the elimination of the gravity switch and the substitution of a sensitized sheet of paper or gelatine film for the circular photographic plate used. We suggest winding the sensitized sheet on the cylinder of a Schultz chronoscope, and see no reason why it should not then be as susceptible to practical use as is the Schultz. The traversing gear of the latter would obviate the present necessity of the gravity switch and allow of the use of this chronoscope as a megagraph without affecting its value in its present distinctive field, that is, as a micrograph.

The instrument is so accurate that the cutting of a screen wire by the side in place of the point of the ogival head of the projectile causes an irregularity in the record. So we may fully expect with its further development to see rewritten the literature on the resistance of the air to projectiles, as well as possibly the thermo-dynamics of the gun itself.

THE LIMIT OF HUMAN ENDURANCE OF HIGH AIR PRESSURES.

[ENGINEERING NEWS.]

The dangers to men working under high pressures of compressed air, due to the pressure itself, and especially to the change from the high to the normal pressure on leaving the air-lock, have long been recognized and studied by engineers and physicians, and it is now well understood that only comparatively young men, of sound constitution, should be employed, that the hours of labor under pressure should be short, that the pressure should be reduced very gradually in the air-lock, that the men should rest after coming out, and that a hospital air-lock should be provided, in which men may be placed and treated with heated compressed air if chilled, afflicted by the "bends" or "caisson disease," or otherwise injured by a too sudden reduction of pressure. A hospital of this kind, as used at the Hudson River tunnel works, was illustrated in our issue of June 14, 1890.

A series of interesting experiments as to human endurance of higher pressures than are usually employed in compressed air work has recently been made by Mr. Hersent, the engineer in charge of the new harbor works at Bordeaux, France, where the quay foundations are being constructed by the compressed air system, and we take the following particulars of these tests from *Engineering*, of London. As the sponge divers descend from 160 to 200 ft. without injury, it was considered that workmen should be able to endure corresponding pressures under the better conditions of an air chamber, and Mr. Hersent therefore formed a commission of doctors to work with him in ascertaining if men could safely sustain a pressure of 70 lbs. per sq. in. The test chamber was fitted with windows, a telephone, electric light and a steam coil, by which any desired temperature could be maintained.

Three men volunteered for the tests; one being a regular compressed-air workman, the second an occasional workman, and the third a man who had only entered the working chamber on a few occasions. These men were subjected to pressures for a length of time, usually about one hour. The tests were commenced with a pressure of about 28.4 lbs. per sq. in., and the pressure increased very gradually, by about 4.27 lbs. per day, to 76.8 lbs. per sq. in., while the time for the pressure reduction was increased about 10 minutes for each 1.42 lbs. increase in pressure. The period of compression was also increased, but to a smaller degree, this being of less importance. All three men sustained without difficulty a pressure of 46.9 lbs., with a reduction period of 56 minutes. One of the men, being indisposed from an independent cause, was then withdrawn. At 58.3 lbs. pressure the man who was used to working in the chamber felt some temporary inconvenience, and at 65.4 lbs. his companion, who was not accustomed to compressed-air work, had to be withdrawn, as he suffered from pains in the side. There was no trace of paralysis, but it was not considered safe for him to continue the test, which was finished by the first man alone, who sustained a pressure of 71.1 lbs. for one hour, the pressure being then reduced in 2 h. 25 mins. When released from the chamber this man took some sulphurous baths, which had cured the pains of his companion, and then underwent the final test, in which the pressure was raised to 76.8 lbs. in 45 minutes, continued for an hour, and then reduced to normal pressure in 3 h. 3 mins. The temperature was increased from 56° F. to 68° F. during the compression, maintained at 68° during the test, and then gradually increased to 86° F. during the reduction of the pressure. The man suffered no inconvenience, with the exception of a tingling sensation, which passed away after a short time. It is considered that, if certain precautions are taken, men in good health can sustain a pressure of 76.8 lbs. per sq. in., that means should be provided for heating the chamber at will, and that good ventilation should be maintained during the reduction of the pressure. As it has been proved that the workmen should rest after leaving the air-lock, especially after working under high pressures, elevators should be provided to bring the men to the surface. These experiments go to show the practicability of men working under compressed air at greater depths than have yet been attempted.

The greatest pressure thus far used in compressed-air work was 52 lbs., corresponding to a head of 120 ft., in the East River Gas Co.'s tunnel, described in our issue of July 11. This was the extreme reached on this work. The ordinary pressure was about 45 lbs., corresponding to a head of 104 ft. At the Limfjord Bridge, in Denmark, men worked for some time at a depth of 113 ft.

THE IMPROVED GATLING GUN.

[IRON AGE.]

The Naval Rapid Fire Gun Board have submitted to Captain Sampson, chief of the Naval Bureau of Ordnance, a report on the trial of the improved gatling gun. In its general features the gun is the same as the 30-caliber gun tested by the board last year. It differs in important details, however. The caliber of the improved invention is .236 and the length of the barrels 26 inches. A change in the firing mechanism has been made, and now the operating is done from the right-hand barrel instead of the lower one. The change allows more time for the operation of the extractor, and reduces the danger of disabling the gun by hang fires. A novel electrical attachment is used with the gun, which permits of about 1800 shots a minute being fired, a remarkable showing.

The improved gatling underwent tests in competition with the Browning automatic gun. Later it will have to meet several foreign inventions. The experiments with the gatling gun began with the firing of 100 rounds deliberately. This was followed by the discharging of 100 rounds rapidly. No time was taken for the first test, but in the second the record was 9 seconds. There were no interruptions to the firing. Then 20 rounds were discharged; time 3 seconds. One miss fire occurred. Forty rounds were fired in 5 seconds, 50 rounds in 6 seconds, 100 rounds in 7 seconds, 200 rounds in 13 seconds and 400 rounds in 37 seconds. One man operated the crank, and two men were at the feed. Later 400 rounds were fired in 30 seconds. Without any difficulty 460 shots were fired in one minute.

In the course of the last test one case containing ten cartridges was split laterally. Then followed the firing of 100 rounds deliberately, every fifth cartridge being a dummy. The experiment was satisfactory to the board. Two hundred shots with the extreme elevation and 200 shots with the extreme depression were then discharged, the time for the first being 24 seconds and for the latter 21 seconds. With the barrel moving in train and elevation, 200 rounds were fired in 30 seconds without any interruption. In these experiments two men successfully operated the cranks.

To determine how quickly damaged parts of the mechanism could be replaced, a test ensued of taking out an old and putting in a new lock; the time was 28 seconds. The board fired the gun 20 times with one lock removed. No interruption occurred, but two unfired cartridges were thrown out. Some ill luck attended the attempt to fire the gun continuously for five minutes. A bullet became jammed in one of the barrels, and in one chamber two cartridge cases were found one against the other, the heads of both having been pulled off. The jams were but temporary. The record of the five minutes' firing was 1980 shots, 40 of which were satisfactory hits. The range was 500 yards. With the range at 1000 yards the number of good hits was ten.

The board then made experiments with the gun having the electric motor fitted on. The motor is attached to the breech of the gun casing by an interrupted screw. The electric current is regulated by a switch, and the connection with the firing mechanism made and broken by a push-button held in the gunner's hand. The weight of the motor and the casing is 106 pounds; their length, 21⅜ inches. The additional length of the gun when the motor is attached is 20 inches. The projection of the central shaft from the breech when the motor is unshipped is $2\frac{7}{16}$ inches. As stated, with the motor in operation, the gun can fire 1800 shots a minute. The board says that several hundred shots were fired, the only interruption being due to the temporary jams in the gun or feed strips, and that the action of the motor was smooth and regular throughout.

PAPER SAILS.

[MARINE RECORD.]

An innovation in yachting circles is now being talked of, nothing less than sails made of compressed paper, the sheets being cemented and riveted together in such a way as to form a smooth and strong seam. It appears that the first process of manufacturing consists in preparing the pulp in the regular way, to a ton of which is added 1 pound of bichromate of potash, 25 pounds of glue, 32 pounds of alum, 1½ pounds of soluble glass, and 40 pounds of prime tallow, these ingredients being thoroughly mixed with the pulp. Next the pulp is made into sheets by regular paper-making machinery, and two sheets are pressed together with a glutinous compound between, so as to retain the pieces firmly, making the whole practically homogeneous.

The next operation is quite important, and requires a specially built machine of great power, which is used in compressing the paper from a thick, sticky sheet to a very thin, tough one. The now solid sheet is run through a bath of sulphuric acid, to which ten per cent. of distilled water has been added, from which it emerges to pass between glass rollers, then through a bath of ammonia, then clear water, and finally through felt rollers, after which it is dried and polished between heated metal cylinders. The paper resulting from this process is in sheets of ordinary width and thickness of cotton duck; it is elastic, air-tight, durable, light, and possessed of other needed qualifications to make it available for light sailmaking.

The mode of putting the sheets together is by having a split on the edges of the sheet, or cloth, so as to admit the edge of the other sheet. When the split is closed, cemented and riveted or sewed, it closes completely and firmly.

THE RAW-HIDE CANNON.

[SCIENTIFIC AMERICAN.]

The cannon held its own against very severe tests. It successfully withstood a pressure of 30,369 pounds to the square inch, but the recoil after this shot broke the trail of the gun carriage, and further tests were impossible, no other carriages being available at the time. The War Department ordered the Ordnance Board to test the cannon carefully. In Syracuse they have been firing the gun privately in an armory for a month past.

The principal claims made for the gun are that it is only about half the weight of an ordinary steel gun, that it is just as durable and much stronger than a steel gun, and that any number of shots can be fired from it in rapid succession without heating it.

The raw-hide gun used July 23 was not a very formidable affair. It was 5 feet 8 inches long and was of 2½ inches caliber. It was mounted on a most elaborate gun carriage, which Mr. Link, the assignee, informed the board was made by the finest wagon-maker in Syracuse. The gun weighs 456 pounds, and, according to the diagram, is made up of layers of steel, raw-hide, and copper wire. The bore is of steel, ¾ of an inch thick at the muzzle and 1½ inches thick at the breech. The raw-hide is 1 inch in thickness at the muzzle and 3 inches in thickness at the breech, and is cut in 4-inch strands. Around the whole is wrapped two layers of heavy copper wire. The gun looked strong enough to stand an ordinary charge, but not an officer present believed that there would be much more than a few bits of the carriage left after the first of the heavy tests had been made.

A PROPELLER LIFE BUOY.

[SCIENTIFIC AMERICAN.]

In an inflatable rubber bag forming at once a seat and a buoy is a metallic bearing sleeve for a shaft on whose outer end is a screw or paddle wheel, waist and shoulder straps preventing the person using the buoy from being washed off. The forward end of the bearing sleeve is forked, the forks being pivoted to an air-tight casing or buoyant chest, against the rear side of which the seat may be folded up. The casing also forms a partial support, and contains the mechanical propelling devices, having at its under side bearings for the horizontal propeller shaft and on its front side bearings for a vertical shaft on whose lower end is a screw whose operation is adapted to uphold the buoy in the water. On the casing is stepped a mast, on which a sail may be set, and a downwardly extending frame supports a pedal shaft, by which may be operated, through a sprocket chain connection, a crank shaft having a bevel gear meshing with a bevel pinion on the vertical shaft, the latter shaft also having a bevel pinion meshing with a bevel gear on the forward end of the horizontal shaft, both shafts and their screws or paddles being thus operated by the pedals and by hand cranks at each side of the casing. There is a rudder on the forward side of the casing, and a compass is mounted just below a lantern supported on a rod in front of the mast. The pedals and crank handles are arranged to be folded, and the blades of the screws fold down upon their shafts, all parts of the device being designed to occupy as small a space as possible when not in use. This device forms the subject of a patent recently issued to M. Francois Barathon, Sr., 21 Boulevard Poissonniere, Paris, France.

SHIPS OF WAR.

[UNITED STATES.]

THE INDIANA.

[AMERICAN ENGINEER AND RAILROAD JOURNAL.]

The Indiana, one of the three coast-line battle-ships authorized by the act of Congress approved June 30, 1890, making an appropriation for the construction of three battle-ships at an individual cost not to exceed $4,000,000, has just been accepted by the Government and placed in commission. The contract for the construction of this vessel was awarded to the William Cramp & Sons Ship and Engine-Building Works, of Philadelphia, Pa. The vessel was launched on February 28, 1893.

The Indiana is built of steel. The hull is protected by belts of heavy armor 7½ ft. wide, 3 ft. of which is above water. This protection runs along both sides of the vessel for a distance of 148 ft. amidships, at the extremities of which the armor turns in toward the center line at an angle of 45° for a longitudinal distance of 24 ft., affording a total broadside protection of 196 ft., and passing around and supporting the armor for the 13-in. gun turrets. On top of this side armor is placed a steel deck 2¾ in. thick, under which are the magazines and machinery. Above this belt of side armor, and extending from redoubt to redoubt, the sides are 5 in. thick with a backing of 10 ft. of coal.

The vessel is cut up forward beneath the water-line, making a powerful ram bow, and doing away with excessive bow waves on account of the easier lines so obtained as well as greatly adding to the manœuvring qualities.

The principal dimensions are: Length on the water-line, 348 ft.; breadth, extreme, 69¼ ft.; draft forward and aft, 24 ft.; displacement, 10,288 tons; sustained sea-speed, 15 knots; normal coal supply, 400 tons.

Between the turrets for the 13-in. guns there is a superstructure in which are placed the 6-in. guns, and above or upon the deck erected thereon are placed the 8-in. guns. A battery of 6-pdrs. is arranged along the top of the hammock berthing and bridge, and 1-pdrs. are placed two forward and two aft, one on either side on the berth-deck. In the tops of the double-topped military mast are placed four Gatling guns, two in each top.

The main battery consists of four 13-in. breech-loading rifles, eight 8-in. breech-loading rifles and four 6-in. breech-loading rifles. In the secondary battery there are twenty 6-pdr. rapid-fire guns, four 1-pdr. rapid-fire guns and four Gatling guns.

In addition to the foregoing offensive phase of the ship, there are six torpedo-tubes, one bow, one stern, and four broadside, two on either side, just abaft and forward of the forward and after barbettes respectively.

The four 13-in. guns are mounted in pairs in two barbette turrets forward and abaft the superstructure on the main deck. The lower part of these turrets, called the barbette, is 17 in. thick, while the turret proper, which rises above this wall of armor, is 15 in. thick.

The 8-in. guns are mounted in pairs in four turrets of similar character, two on either side, on the forward and after extremities of the superstructure deck.

The four 6-in. guns, two on each side, are placed amidships on the main deck. These guns will have local protection in addition to splinter bulkheads, shields and automatic shutters.

The 13-in. guns have an effective arc of fire of 270°. These guns are mounted about 17½ ft. above the water-line. The 8-in. guns are about 25 ft. above the water-line, and are high enough to fire over the 13-in. turrets. These guns have a radius of action of 164°.

The engines are of the twin-screw, vertical, triple-expansion, inverted-cylinder type; diameter of cylinders being as follows: high pressure, 34.5 in.; intermediate pressure, 48 in.; low pressure, 75 in., with a common stroke of 42 in. There are four double-ended boilers, 18 ft. x 15 ft. in diameter, and two single-ended boilers (donkey), 8½ ft. x 10 ft. in diameter. Each boiler and engine is in a separate watertight compartment, in order to localize possible injury.

While the normal coal supply is 400 tons, there is a coal bunker capacity of 1800 tons.

The complement will consist of 475 persons—officers and men. Good quarters and accommodations have been provided, and all the latest sanitary improvements will be installed to insure efficiency and thoroughness in lighting, ventilating, and draining.

While the Indiana was under construction there were innumerable croakers who were ready with all sorts of predictions that the vessel would be so top-heavy that her roll in a seaway would be excessive and dangerous. Great interest was accordingly manifested in her performance on her first trip to sea. On leaving the yard the first run was made to the Delaware Breakwater, where she anchored for the night, to wait for a heavy northeasterly gale to subside. The following morning the vessel put to sea, where, although the gale had abated, there was still a heavy sea running, and all on board were in expectation of being badly pitched and rolled about. Some of the members of the Naval Trial Board got out their instruments for registering the roll of a ship, and were prepared to note the number of degrees. To their surprise the ship rode each wave lightly, and the greatest roll noted and reported was only 1½°.

On October 16 the vessel made a preliminary run over the official course off Cape Ann, Mass., and made an average speed of 15.31 knots over a distance of 62 nautical miles. On this run the absence of the usual vibrations made by the powerful engines of a big ship were particularly noticeable. Another feature was the bow wave cast off by the ship. The torpedo-tube in the bow threw up quite a wave, but the bow of the boat itself cleft cleanly through the water, and the lateral waves, instead of extending many feet on each side of the ship, did not extend much more than 15 ft., and then they converged sharply and clung to the vessel's side, leaving no side wave at all.

The official trial was made on October 18 between Cape Ann and Boone Island. The run to Boone Island was made against the tide in

2 hours, 2 minutes and 7 seconds, with an average speed of 15.24 knots. On the return the passage was made in 1 hour, 55 minutes and 35 seconds, making a total of 3 hours, 58 minutes and 28 seconds for the whole run, or an average speed of 15.61 knots, which was .61 knot above the contract requirements. There was a remarkable burst of speed at the latter end of the run, where a speed of 16.3 knots was attained. At this time 11,800 H. P. were developed. The average H. P. shown during the trial was 9700, which is 700 more than the contract requirements. The maximum revolutions of the screws were 131, and the average revolutions were between 128 and 130. The average steam pressure at the boilers was 165 and at the engines 161. The average water pressure in the fire-rooms was 1 in., and the average temperature was 105°.

After the run was over a helm test was made. The ship was turned in a circle of 400 yds., or 200 less than it took to turn the cruiser New York, and she answered her helm with great promptness.

[ENGLAND.]

THE JUPITER.

[THE ENGINEER.]

The Jupiter is the fifth to be launched of nine similar battle-ships, forming part of what is known as the "Spencer Programme," projected shortly after the Salisbury Ministry made way for that of Mr. Gladstone in 1892. A description of H. M. S. Magnificent and Majestic has already been given. It will be unnecessary, therefore, again to enter into any elaborate description of the class, but a few of the general particulars may be recapitulated. The dimensions are: Length between perpendiculars, 390 ft.; breadth, extreme, 75 ft. 9 in.; depth, moulded from upper deck, 44 ft. 9 in.; mean draught, 27 ft. 6 in.; displacement, 14,900 tons. The protection consists of an armor belt of Harveyed steel, 9 in. in thickness, which extends for 215 ft. At the ends are transverse armor bulkheads, also of Harveyed armor, the lower part being 12 in. thick and the upper 9 in. In addition there is a protective deck of from 3 in. to 4 in. in thickness, extending from end to end of the ship. This deck is arched, and is intended to protect the magazines and machinery from fragments of shells and falling shot. At the bottom the belt, which extends up to the main deck and is about 15 ft. broad, is 5½ ft. below the water-line and before and abaft the belt; the protective deck is at a lower level than amidships, so that the ends of the ship are protected by an under-water steel deck.

As regards armament and its disposition the heavy guns are four in number, of 46 tons weight and 12-in. caliber. They will be mounted in pairs in redoubts of Harveyed armor 14 in. thick above the main deck and 7 in. below, and extending from the protective to a few feet above the upper deck. The freeboard of the vessel is unusually great, the center of the guns being about 27 ft. above the water level. The secondary armament consists of twelve 6-in. quick-firing guns, all mounted in armored protective casemates on the main and upper decks. There are also a number of quick-firing and machine guns variously disposed, and five torpedo tubes, four of which are in compartments below water-level, from which they are discharged, thus obviating the risk of an enemy's fire exploding them prematurely. The spaces below the protective deck at the ends of the ship are largely occupied with torpedoes and ammunition, and a passage under the protective deck gives access to ammunition tubes of solid armor, leading up to the neighborhood of each of the guns.

The machinery space is divided by means of longitudinal and transverse bulkheads into six water-tight compartments, two of which are devoted to the main engines, and four for the boilers. The engines driving four-bladed twin screws are of the vertical inverted triple-expansion type, of an estimated collective indicated horse-power of 12,000. The speed on trial is to reach about 17½ knots. The boilers, eight in number, are of the ordinary single-ended cylindrical return-tube type. A large coal capacity is provided, there being space for 1800 tons in side bunkers partly above and partly below the protective deck. The steering gear, capstan engine, ventilating and air-compressing engines and the dynamos, all of which are essential to the fighting efficiency of the vessels, are arranged at the ends of the ship below the protective deck. In order to reduce the rolling to a minimum, deep bilge keels are fitted for the greater part of the vessel's length. The hull form, although very fine at each extremity, is tolerably full amidship, the coefficient of fineness below the water-line being .65.

The Venus.

[The Steamship.]

On the 5th September, H. M. S. Venus, second-class protected cruiser for the British Government, was launched from the yard of the Fairfield Shipbuilding and Engineering Company, Limited, Govan. The following is a detailed description of the vessel:

H. M. S. Venus is a second-class protected cruiser, being one of the improved Talbot class of vessels now building in the dockyards. Her dimensions are: Length between perpendiculars, 350 ft.; breadth, extreme, 54 ft.; displacement, 5600 tons. The hull is built of Siemens-Martin steel throughout to Admiralty requirements, on the usual principle adopted in warship construction. She has a cellular bottom extending the full length of the engine and boiler spaces, and before and abaft these the water-tight flats of the magazines, etc., continue the double-bottom right to the stem and stern. Under the protective deck the side compartments for the full length of the boiler space are utilized for stowing coal, and additional cross bunkers are introduced at each end of the boiler rooms, thus giving a complete casement of coal round each set of boilers. The hull is subdivided by longitudinal and transverse bulkheads into numerous water-tight compartments, the number of water-tight doors having been reduced to a minimum, and all being worked from the main deck as well as from below. The stern post, struts, and stem are of phosphor bronze. The vessel has a ram stem, and the structure behind is especially strong and efficiently connected to the general framework of the vessel, with a view to the contingency of ramming. The rudder, also of phosphor bronze, is of the balanced type, and controlled by Harfield's compensating gear below the protective deck. The vessel being intended for foreign service and long cruises at sea, in which the maintenance of a uniform speed becomes essential, she has been completely covered to above the load water-line with teak of a minimum thickness of 3½ in. and coppered.

To secure steadiness of gun platform, so necessary in a vessel intended for war purposes, bilge keels extending for about half the vessel's length amidships have been fitted. The protection of the vessel consists of a curved deck extending from stem to stern, ranging from 3 in. to 1½ in. in thickness, covering the whole of the propelling and steering machinery, boilers, magazines, etc. In addition, the engines are protected by an armored citadel of Harveyized steel, giving protection from raking fire. The reserve bunkers are on the protective deck over the machinery space, and whilst affording a water-line belt of coal protection they, being subdivided into water-tight compartments, give additional security in the event of damage. An armored conning tower of Harveyized steel is placed forward, fitted up with the usual means of navigating the vessel and directing operations while in action, the whole of the connections for which are protected by a steel tube extending to the protective deck.

An additional director tower is provided at the after end of vessel for operating the torpedoes, and conning bridges are fitted both at the fore and after ends for navigating the vessel under ordinary conditions, with the usual compasses, steering-wheels, etc. Three search-lights are operated from these bridges, and the vessel throughout is fitted with a complete installation of electric light. The coal capacity is normally 550 tons, but provision has been made for carrying a greater quantity if necessary. The magazines and shell-rooms are of ample capacity, and are conveniently situated for working the quick-firing guns, special gear being supplied for manipulating the ammunition. The ventilating and pumping arrangements of the vessel are on the usual elaborate scale observed in ships of this class. The accommodation for the officers and crew is of an ample nature, the latest fittings being provided. The complement of men and officers reaches 450 all told. Her armament consists of five 8-in., six 4.7-in., and eight 12-pounder, all quick-firing guns, and a number of smaller guns. The guns are all protected by extra thick shields. Two submerged torpedo tubes are fitted forward and one discharging above water aft, capable of working the latest pattern torpedoes.

The ship has two masts, fitted with military tops for working machine guns, and rigged with fore and aft steadying sails. A signal yard is fitted on the foremast, as well as the new multiple fire signal lamp at masthead.

The propelling machinery consists of two sets of triple-expansion engines, fitted in two separate engine-rooms, each set having three inverted cylinders and three cranks. The high-pressure cylinders are 38 in. diameter, the intermediate-pressure 49 in. diameter, and the low-pressure 74 in. diameter—all adapted for a stroke of 3 ft. 3 in. The cylinders are separate and independent castings, each fitted with a cast-iron liner, and steam jacketed. Each high-pressure cylinder is fitted with a piston valve, and the intermediate and low pressure are each fitted with double-ported slide valves, all worked by double eccentric and link-motion valve gear. Balance cylinders and compensating rings are fitted to the intermediate and low pressure valves.

The reversing engines are of the all-round type, with worm and wheel gear; and all the reversing levers are fitted with a slot and adjusting screw to allow of the expansion in the cylinders being altered. The back columns are of cast iron, fitted with separate guide faces pinned on, and the front columns are of forged steel, the engines being arranged with the starting platforms amidships. The main condensers are of cast brass, and placed at the wings; the steam is condensed outside the tubes, the circulating water passing through them. There are two large centrifugal pumps of brass worked by independent engines, one in each engine-room, and arranged with a cross connection so that either or both condensers can be supplied with circulating water from either pump. The feed, bilge, and fire-engines are all independent of and separate from the main engines. They are arranged on the center-line bulkhead, the steam being supplied by a special range of pipes. All the exhaust steam is led into an auxiliary condenser of cast brass, having a small air and circulating pump, one of these condensers being fitted in each engine-room. Everything, it will be seen, is in duplicate about the machinery department. The crank, thrust, and propeller shafting is of forged steel and hollow. The crank pins are fitted with centrifugal lubricating apparatus. The propellers are of gun metal, each propeller having three adjustable blades, and constructed to work forwards. A feed-water filter is fitted between the air pump and feed-water tank to prevent any impurities reaching the boilers. Steam is supplied by eight single-ended boilers, each fitted with three corrugated furnaces, and adapted for a working pressure of 155 lbs. The boilers are arranged in two water-tight compartments, the steam pipes being so arranged that the steam from the boilers in either boiler-room can be used for the engines in either or both engine-rooms. Fans and engines are fitted in the stokeholds, and the arrangement is such that the boilers can either be worked with natural draught with fans not working or with closed stokeholds and forced draught.

It is contemplated that the vessel will attain a speed of 19½ knots under usual conditions at sea with the power provided.

TORPEDO-BOAT DESTROYERS WITH WATER-TUBE BOILERS.

[ENGINEERING.]

Name.	Builders.	Length of Vessel.	Description of Boilers.	Speed on Three Hours' Official Trial.
		ft.		knots.
Boxer	Thornycroft	201.5	Thornycroft	29.17
Surly	J. & G. Thomson	200	Normand	28.05
Ardent	Thornycroft	201.5	Thornycroft	27.97
Bruizer	“	201.5	“	27.97
Starfish	Naval Construction Co.	190	Blechynden	27.97
Janus	Palmers	.....	Du Temple	27.80
Decoy	Thornycroft	185	Thornycroft	27.76
Daring	“	185	“	27.70
Hornet	Yarrow	180	Yarrow	27.63
Salmon	Earle's	200	“	27.60
Shark	J. & G. Thomson	200	Normand	27.59
Banshee	Laird	210	“	27.57
Ferret	“	195	“	27.51
Rocket	J. & G. Thomson	200	“	27.37
Contest	Laird	210	“	27.36
Sturgeon	Naval Construction Co.	190	Blechynden	27.16
Dragon	Laird	210	Normand	27.14
Skate	Naval Construction Co.	190	Blechynden	27.10
Handy	Fairfield	194	Thornycroft	27.04
Lynx	Laird	210	Normand	27.00

The above list gives the trial speeds of all the torpedo-boat destroyers, with water-tube boilers, of which we have records. The speeds given are those obtained on the three hours' official trials, with the contract weight of 30 tons in the shape of coal, spare gear, etc., on board. It is a notable fact that some of these vessels have obtained a better speed on the full three hours than was made during the six runs on the mile. This is to be accounted for by the load becoming lighter owing to the coal being burnt.

Vessels with the locomotive boiler are not included in our table. Such vessels are, it will be remembered, allowed a knot less than those having water-tube boilers, that is to say, the contract three hours' speed is 27 knots for water-tube boilers and 26 knots for craft with locomotive boilers. Under these circumstances it would not be fair to put the latter in a list of order by merit with the other craft.

The Boxer, one of the five boats built by Messrs. Thornycroft & Co., it will be seen, heads the list, standing conspicuously first, with a lead of over a knot, or a total superiority of 3½ nautical miles on the three hours' run. Up to a short time ago she was not only the fastest vessel in the British Navy, but also the fastest in the world. Within the last month, however, her speed has been exceeded by two vessels. The first, the Sokol, although constructed for a foreign power, has been built in England by Messrs. Yarrow & Co. It will be sufficient to say that she made a speed of 29.76 knots on her three hours' trial. Her length is 190 ft., and her width 18 ft. 6 in. The other vessel referred to, the Forban, built by Messrs. Augustin Normand & Co., of Havre, is, we regret to say, British neither in ownership nor construction. The Forban is not a torpedo-boat destroyer, but a large first-class torpedo-boat. Her length is 144 ft. 4 in., maximum breadth on load line 14 ft. 6 in., extreme breadth 15 ft. 2 in., depth 10 ft., displacement on trial about 125 tons, and displacement fully loaded 136 tons. The boilers are of the Normand water-tube type, and the engines triple-expansion. The load of armament, coal, crew, etc., was 16 tons. On an hour's run the mean speed was 31.029 knots. Whether the speed would have been maintained on a three hours' run is a matter upon which we need express no opinion.

There yet remain several of the 42 destroyers to complete their trials—one by Yarrow & Co.; three by J. S. White, of Cowes; two by Palmer's Shipbuilding Company; two by Doxford & Sons, of Sunderland; two by Hanna, Donald and Wilson, of Paisley; one by Earle's Shipbuilding and Engineering Company, of Hull; two by Armstrong, Mitchell & Co.; three by Hawthorn, Leslie & Co.; two by the Fairfield Company; and one by the Thames Iron Works. Some of the above have locomotive boilers. If we add to the above the Dasher, Charger, and Havock, the three boats by Yarrow & Co., with locomotive boilers, which have passed their trials, we have the total number of 42 boats ordered.

The new torpedo-boat destroyers, which are to follow the 42 above dealt with, were originally intended to be 20 in number. Their guaranteed speed is 3 knots faster than that of the first lot, namely, 30 knots. We believe, however, that up to the present only 12 of these vessels have been ordered. They are not all of the same dimensions, but some, at any rate, will not exceed in size the largest of the 42. The extra speed will, therefore, have to be obtained chiefly by an increase in power. The orders for the 12 boats now being constructed have been equally divided between Thornycroft's, Laird's, and Thomson's. All will have water-tube boilers, the Mersey and Clyde vessels those of the Normand type. The *Western Morning News* states that Messrs. Thornycroft have guaranteed 5400 indicated horse-power for their vessels, Messrs. Laird 6000, and the Clydebank firm 5800 indicated horse-power. What will come out in practice of course remains to be seen. No doubt in the new boats advantage will be taken of recent experience to lighten the scantling of the hulls, but whatever the resources brought to bear, it will be anxious work to get the guaranteed speed. According to the *Western Morning News*, the Thornycroft boats are each to be 272 tons displacement, and the other eight 300 tons apiece. The load, we understand, is to be 30 tons, as with the former craft, so that the larger vessels will have an advantage of a smaller proportionate deadweight. The new boats are named as follows: Messrs. Thornycroft's vessels, Desperate, Fame, Foam, and Mallard; Messrs. Laird's, Quail, Sparrowhawk, Thrasher, and Virago; Messrs. J. and G. Thomson's, Brazen, Electra, Recruit, and Vulture.

[FRANCE.]

THE BOUVINES.

[THE ENGINEER.]

The small French battle-ship Bouvines, which was launched in 1892, is now completed. She is one of a group of four war vessels originally intended to have been built upon the design of a modified Furieuse, viz., the Jemmapes, Valmy, Bouvines, and Tréhouart. But in consequence of the serious disposition to instability which the Furieuse and Terrible displayed during manœuvres in an ordinary Mediterranean gale, the dimensions of the last two vessels were modified, the beam being increased 12 in. and the freeboard raised about 8 ft. forward, whilst, to compensate partially for the consequent elevation of the forward gun, the caliber of both of them in the main armament was reduced from 34 centimeters (13.4 in.) to 30 centimeters (11.8 in.).

The principal dimensions, etc., of the Bouvines and Tréhouart are as follows, and they differ very slightly from those belonging to the other two vessels, except as regards the particulars aforesaid: Length at the water-line, 284 ft.; beam, 58 ft. 8 in.; draught, 22 ft.; displacement, 6610 tons; indicated horse-power, 8400; speed, 17 knots; coal capacity, 300 tons. An armored belt of steel extends from stem to stern, 17¾ in. in thickness above and 10 in. in thickness below the water-line, this being surmounted by an armored deck of steel 4 in. thick. The turrets for the main armament are oval, and armored with 14½-in. steel plates. They rest upon armored redoubts 12½ in. thick, built upon the armored deck.

The armament consists of two 11.8-in. guns, as before-mentioned, eight 10-centimeter (4 in.) quick-firers, and fourteen smaller quick-firers and machine guns. The main armament is very powerful, the 30-centimeter gun being 45 ft. in length and capable of piercing 35.7 in. of armor. The great length of the weapon is an obvious advantage. It is capable of being fired in a horizontal line, either direct ahead or direct astern, without endangering the integrity of the deck or the structure of the ship; the muzzle projecting so far forward and aft as to clear them from the effect of "blast." Its height above the deck also necessarily conduces to this end, and gives additional gun command—a very important feature. The position of the eight 4-in. quick-firers is equally good. They are all upon the superstructure, so that when the scuttles are closed the hull of the vessel has no gun-ports to attract observation and fire, whilst each gun is within a stout and capacious steel shield. Many of the smaller quick-firers are equally well placed within the shelter of the fighting tops, of which there are two independently of the conning tower, upon the single fighting mast. Four of the 10-centimeter quick-firers, as well as the guns of the main armament, can be trained axially ahead or astern at the same time. The position of the smaller quick-firers in the fighting tops is one of considerable security, and well thought out by the designers of the vessel, so long as the mast itself remains intact. Here the naval architects of France have adhered to their old policy of providing for "top-fire," which proved so terribly destructive to both officers and upper-deck men at Trafalgar and other actions of that period. We should be sorry to see the decks of our vessels encumbered with the towering monstrosities which rise, like the minarets of a mosque, from the Hoche and Magenta; but, after the experience of the unfortunate crews of the fighting tops in the recent naval actions between China and Japan, we confess that it would be satisfactory to know that some attention was being paid to the safety of the men who would have to occupy this position in the event of the action with our own vessels. The shallow thinly plated cheese-boxes, which contain, upon the Majestic class, no less than four 3-pounder Hotchkiss guns, would be cleared of their occupants in a few moments by the machine-guns of the crews occupying the upper top of the Bouvines, whilst these last would be in comparative security, as they could not be seen.

On the whole we consider that two, at least, of the four new French coast-defense battle-ships are very excellent and serviceable little vessels, and as their cost is less than half that of an ordinary sea-going unit of this class, it is almost a question whether Lord Brassey is not right in his pleading for more armored vessels of a medium size. It must be remembered that the Bouvines, drawing only 22 ft. of water, could go in and out of estuaries which would be denied to the Royal Sovereign and Magnificent, and the fault of small coal capacity could be easily remedied. The quantity of eggs which we are now placing in our 15,000-ton baskets is terrible to contemplate.

THE NEW 23-KNOT CRUISERS.

[LE YACHT.]

For some years France has been distanced by both England and the United States in the construction of high-speed cruisers, and she does not at the present day possess a single vessel that could be sent against the commerce destroyers Columbia and Minneapolis, and still less against the gigantic English cruisers Powerful and Terrible, whose speed and steaming power make them the rulers of the ocean.

The relative unimportance of her mercantile navy does not demand on the part of France as great sacrifices as would be required from England to protect her commerce. Looking at protection in this light, the Republic would need very few cruisers in time of war. Assuming, however, that she may be involved with another nation possessing a powerful commercial navy, a different view may be taken of the subject. The destruction of that commercial navy, or more modestly speaking, the crippling of the immense traffic which it is the means of carrying, would be an important factor of success that can hardly be overestimated.

It was such consideration as this that impelled President Faure, then minister of marine, to urge upon the French Chambers the necessity of building a certain number of cruisers with a speed of twenty-three knots, inserting in the estimates a clause providing for the immediate placing on the stocks of two of these vessels. There were some delays in perfecting the scheme, but the awards for the new constructions are by this time in the hands of the Forges et Chantiers de la Méditerranée, and the Société de la Loire, each company to build one vessel from their own design.

The cruisers will be 135 meters long, 16.7 meters beam, with a draught not exceeding 7.5 meters, and a corresponding displacement of about 8200 tons. Their defensive power will consist of an armored deck 50 mm. thick of a polygonal shape, with a cellulated space between this protective deck and the orlop deck, an arrangement lately adopted in the French constructions.

The armament will consist of two guns of 16 cm., six of 14 cm., and ten R. F. of 47 mm. As may be readily seen, the offensive power of these vessels is rather weak, considering their great displacements, but the department sought above all to avoid the construction of enormous and costly ships like the Powerful and Terrible, whose displacements of 15,000 tons are nearly double those of the new French vessels. Given the speed to be attained, and the necessity of great endurance, it became necessary to reduce the armament to a minimum. The installation of an additional gun would have entailed an increase in the displacement, owing to the weight, not only of the gun, but its necessary adjuncts—ammunition hoists, etc.—and also because to keep up the same speed with the extra weight it would be necessary to increase the power, and consequently the weight of the machinery. Finally the coal supply must also be increased if it be proposed to have the same radius of action. In nearly every instance the last two increases, being corollaries of the first, greatly exceed it. It has been calculated that the addition of a 14-cm. gun to the battery would result in an increased displacement of from 500 to 600 tons. Besides, the actual batteries are quite sufficient for the duty for which the vessels are intended, namely, the capture of merchant vessels, fighting mail steamers armed as auxiliaries, or cruisers of their own type.

In general arrangements these vessels do not present any characteristic features apart from their triple screws, three engines, and protection for the 16-cm. guns.

They are protected cruisers with a cellular subdivision (tranche cellulaire), in which the motive power and coal capacity have been greatly increased. The lower parts are entirely taken up by the engines, boilers, and shell-rooms. The engines are placed in one athwartship compartment and separated from each other by longitudinal water-tight bulkheads, each engine having a capacity of 8000 I. H. P. The spaces on each side of the engines serve as water-tanks to feed the boilers. Forward of and abaft the compartment occupied by the engines are the boilers, thirty-six in number, distributed in six athwartship rooms.

The boilers are of the Allest type, with a heating surface of 150 square meters.

Between the protective and orlop decks, in the space forming the cellular subdivision, are distributed the additional coal bunkers, storerooms and supplies of all kinds. On the gun-deck are arranged four search-lights whose low luminous rays pass under the batteries. The 14-cm. guns are in fact placed on the main deck; four of them fire through ports cut in the cants of the redoubt, two forward and two aft; the other two are in sponsons. All of these guns are in casemates, that is, they are worked in the interior of an armored redoubt into which runs an ammunition tube. The bulkheads next the sides have a protective plate of 40 mm., the sides themselves being 60 mm. thick. Finally, the cants, or cut-off angles, being exposed to a more direct fire, have plates 120 mm. thick. Armor shields of 120 mm. revolve with the guns and completely close up the ports.

These arrangements for ordnance of modern caliber seem preferable to installations in revolving turrets. The absence of pivots and machinery renders the redoubt lighter than the turret. Moreover, the space for working the gun is larger, access to the piece is very easy, and finally, a small supply of ammunition may be piled up in the redoubt, which may in a measure obviate a possible mishap to the ammunition tube or hoist. The 16-cm. guns are installed on the main deck, and fire directly ahead and astern, being protected only by revolving shields. No provision is made for fighting tops in these vessels; they will have pole masts like ocean mail steamers, with crow's-nests fitted with search-lights. It is only natural to build vessels intended to prey on the enemy's commerce to simulate ocean mail steamers, and the omission of the military mast is an excellent idea. Captains of cruisers have often complained about their fighting tops, remarking that in war time their vessels would be recognized the instant their military masts showed a little above the horizon, thus making it impossible to deceive the adversary for a single moment. Following the example of the English in the construction of the Powerful and Terrible, the French will give their cruisers stems and sterns similar to those of transatlantic steamers. From a military point of view they will lose in appearance, but in weapons of war the object to be attained takes precedence over all others.

The new cruisers will no doubt be superior in speed to all vessels of a similar class now afloat or in process of building. Their plans of construction and the proportions of their machinery give hopes that the speed of twenty-three knots will be easily attained, if not surpassed.

The Powerful and Terrible were designed for 22 knots, and they may attain that speed; but it must be remembered that experience has demonstrated that in current practice the American commerce destroyers can only exceed that speed when above their load-lines. As to coal capacity, which is of paramount importance to France, who in war time would not possess a single secure coaling station, the new vessels are everything that can be desired. Their bunkers can contain 1500 tons of coal, a quantity sufficient to steam ten thousand miles at a speed of 12 knots, or nearly half the circumference of the globe.

Other projects are before the Bureau Technique, and although it is yet premature to discuss them, sufficient is known to point out some tendencies that are quite interesting. I refer to the increase in the coal-carrying capacity, and consequent steaming power, the decrease in the importance of armor, and the abandonment of enormous displacements with their extravagant costs.

J. L.

[ITALY.]

VESSELS IN PROCESS OF CONSTRUCTION.

[MILITÄR WOCHENBLATT.]

The following ships are in process of building:

I. Battle-ships, 1st class.—L'Ammiraglio Saint-Bon at Venice, and the Emanuele Filiberto at Castellamare; length 105 meters, beam 21.12 meters, displacement 9100 tons, horse-power 13,500, speed 18 knots, nickel-steel armor of 25 centimeters above, and 15 centimeters at water-line. Battery: 4 B. L. R.'s of 25.4 cm., 8 of 15.2 cm., 8 of 12 cm., 6 of 57 mm., and 4 torpedo tubes.

II. Protected cruisers (battle-ships, 2d class).—1. The sister ships Carlo Alberto and Vittor Pisani; the former at Spezzia, the latter at Castellamare. Dimensions: length 99 meters, beam 18 meters, displacement 6500 tons, 13,000 H. P., 18 knots speed, a 15-cm. nickel-steel armor-belt, two-thirds length along water-line. Battery of twelve (12) 15.2-cm., six (6) 12-cm., ten (10) 57-mm. guns, 4 torpedo tubes. 2. The Garibaldi and the Varese, each 100 meters long, 18.2 meters beam, 6840 tons displacement, 13,000 horse-power, 20 knots speed.

III. Unprotected cruisers.—Puglia and Elba, sister ships. Length 83.2 meters, 12.43 meters beam, 2550 tons displacement, 7000 horse-power, speed 20 knots; armed with four (4) 12.5-cm., six (6) 12-cm., and eight (8) 57-mm. guns.

IV. Smaller vessels.—1. Calabria (fifth class), of Lombardia type. Length 73 meters, beam 12.8 meters, displacement 2470 tons. 2. Governolo (sixth class). Length 56.4 meters, beam 10.23 meters, displacement 1255 tons, 1000 horse-power, 12 knots speed. 3. Caprera (sixth class). Length 70 meters, beam 8.35 meters, displacement 853 tons, 4000 horse-power, 20 knots speed. The batteries of these vessels consist of four (4) 12-cm. and four (4) 57-mm. guns.

[GERMANY.]

TWO NEW CRUISERS.

[DEUTSCHE HEERES ZEITUNG.]

The contracts for the two new cruisers (Ersatz Freya), K and L, allowed by the last session of the Reichstag, will soon be awarded. The specifications show that they are to be of entirely different types from the cruiser Gefion. They are based on the latest types of protected cruisers in the navies of England, United States and Russia. Built entirely of steel, they are unsheathed, which seems to indicate that they will be destined for service with the battle-ships rather than for duty in foreign waters, a supposition that is accentuated by their heavy armaments. The batteries are to consist of 2 21-cm. guns of 40 calibers length in armored revolving turrets; 2 15-cm. R. F. guns of 40 calibers length, likewise in revolving turrets; 4 15-cm. R. F. guns, 40 calibers, in armored casemates; 10 8.8-cm. R. F. guns of 30 calibers length, with gun shields; 10 37-mm. magazine guns, and 4 8-mm. Maxim guns. These 30 guns, 28 of which are rapid-fire, give a powerful offensive strength, further heightened by 3 under-water torpedo tubes of 45 cm. caliber, one in the bow and two broadside. The strongly arched protective deck extends the full length of the ship. Further protection is afforded by a cofferdam of cork 2.5 meters high, 70 cm. thick, extending alongside over 70 meters in length. There are numerous watertight compartments. The vessels are to have three independent engines in separate compartments. The contract speed will probably be 21 knots, with 10,000 horse-power. The displacement to be from 5650 to 6100 tons. Length 105 meters, beam 17.4 meters, draught 6.25 to 6.61 meters. To be finished in 2 years.

H. G. D.

[ARGENTINE REPUBLIC.]

THE BUENOS AIRES.

[THE ENGINEER.]

The Buenos Aires is a steel ship, sheathed and coppered, and is of the following principal dimensions: Length between perpendiculars, 396 ft., over all 424 ft.; breadth, extreme, 47 ft. 2 in.; and designed mean draught, 17 ft. 7 in., at which her displacement is 4500 tons. Her propelling machinery, which has been constructed by Messrs. Humphrys, Tennant & Co., of Deptford, consists of two sets of four cranked triple-expansion inverted-cylinder engines, having 40-in. diameter high-pressure, 60-in. diameter intermediate pressure, and two 66-in. diameter low-pressure cylinders, all with a piston stroke of 36 in., steam for which is supplied by four single-ended and four double-ended cylindrical return-tube boilers, the tubes being fitted with Messrs. Humphrys' patent ferrules. Owing to the fog on the day of the trials, and the delay occasioned by it in getting the vessel free from her moorings, she had to be put on the measured mile as soon as she was clear of the river's mouth, and before her engines could be got up to their full speed or power. As the conditions of the trial were that the ship should run for six consecutive hours with natural draught, or with not more than ½ in. of air pressure in the stokeholds, and during that time make six runs on the measured mile with and against the tide, it was elected to make the mile runs first, and from them deduce the speed attained during the remainder of the six hours' contract running time.

The condition of the weather having prevented the vessel getting under way as early as was intended, the first two runs on the mile, which were made in 2 min. 47½ sec. and 2 min. 34 sec. respectively, although they exceeded the contract speed, could not be taken as a criterion of what the ship was capable of attaining, as the succeeding four runs were made at a mean speed practically of twenty-three knots an hour. The mile runs being completed, the vessel was then headed south, and the remainder of the contract time run off, the resultant mean speed throughout the whole of it being 23.202 knots an hour. During the running the engines averaged 151 and 151½ revolutions per minute for port and starboard respectively; the mean boiler pressure was 155 lbs. per square inch, the vacuum 28 in. to 29 in., and the total indicated horse-power developed 14,000.

The Buenos Aires is constructed with a steel protective deck throughout the whole of her length, 3 in. thick on its sloping sides, and 1½ in.

thick on the flat parts, the machinery space being protected with inclined armor 5 in. thick. For her size, the ship is very powerfully armed, as she carries four 8-in. quick-firing guns on the upper deck, four 6-in. guns at the ends of the battery, six 4.7-in. guns disposed between each pair of 6-in. guns in the battery, sixteen 3-pounder guns—eight being on the main deck and four on the bridges—together with eight 1-pounder guns distributed in the tops of the two military masts. The ship is also fitted with five torpedo tubes, all above water.

TABLE SHOWING ARMAMENTS OF SHIPS, ESTIMATES, RATES OF FIRE AND OTHER ELEMENTS. [THE ENGINEER.]

Name of vessel.	Displacement.	Speed.	Armament.	Muzzle energy per gun.	No. of rounds per gun.	Tot'l energy of fire of each class of gun per min.	Tot'l energy of fire per ton displacement	Perforat'n per gun of wrought iron.	Vessel's belt-armor nature and thickness.	Equiv. of belt-armor in wrought iron.
	Tons.	Knots.		Foot-tons.		Foot-tons.	Foot-tons.	Inches.	Inches.	Inches.
Royal Sovereign class ...	14,150	18.0	4 67-ton	35,230	7 in 12 min.	82,203	20.7	34.2	18 compound	22.5
			10 6in. Q. F.	3,356	16 in 3 min.	178,987		16.1		
			16 6-pr. Q. F.	137.5	10 in 1 min.	22,000		3.7‡		
			12 3-pr. Q. F.	80.3		9,640		3.1‡		
						292,830				
Majestic and Magnificent	14,900	17.5	4 12in. 46-ton (wire)	33,940	3 in 4 min.	101,820	26.4	38.5	9 treated	17⅜
			12 6in. Q. F.	3,356	16 in 3 min.	214,784		16.1		
			16 12-pr. Q. F.	425	10 in 1 min.	67,680		5.0		
			12 3-pr. Q. F.	80.3		9,636		3.1‡		
						393,920				
Blenheim	9,000	21.6	2 9.2in. 22-ton	10,910	2 in 3 min.	14,547	22.9	22.9	—	—
			10 6in. Q. F.	3,356	16 in 3 min.	178,987		16.1		
			16 3-pr. Q. F.	80.3	10 in 1 min.	12,848		3.1‡		
						206,382				
Powerful and Terrible...	14,200	22.0	2 9.2in. 22-ton	10,910	2 in 3 min.	14,547	21.6	22.9	—	
			12 6in Q. F.	3,356	16 in 3 min.	214,784		16.1		
			16 12-pr. Q. F.	423	10 in 1 min.	67,680		5.0		
			12 3-pr. Q. F.	80.3		9,636		3.1		
						306,647				
Victory in 1805....... ...	2,162	—	30 32-prs.	489.6	Taken at an average of 2 rounds in 3 min.	14,688	—	—	—	
			30 24-prs.	417.2		12,516				
			32 12-prs.	275.1		8,803.2				
			8 12-prs. (short)	182.1		1,456.8				
			2 68-pr. carronades.	699.8		1,399.6				
			2 32-pr.	426.4		852.8				
						39,716.4				
Buenos Aires.......... .	4,500	22.9	2 8in. (45 cal.) Q. F.	10,300	4 per min.	82,400	67.7	26.1	—	—
			4 6in. (45 cal.) Q. F.	4,688	*6 per min.	112,512		20.7		
			6 4.7in. (45 cal.) Q. F.	2,061	8 per min.	98,928		15.2		
			12 3-pr. Q. F.	91.7	10 per min.	11,004		3.1		
						304,844				
Esmeralda...........	7,300	—	—	—	—	526,884	72.2			
Rurik...	10,923	18.0	4 8in.	4,943	2 in 3 min.†	13,181	16.39	15.0	10 compound	12.5
			16 6in.	2,682	1 per min.	42,912				
			6 4.7in. Q. F.	2,061	6 per min.	74,196				
			18 small pieces, taken as 10 12-prs.	423	10 per min.	42,300				
			8 3-prs.	80.3		6,424				
						179,013				
Rossia...........	12,130	20.0	4 8in.	4,943	2 in 3 min.†	13,181	38.84	15.0	—	—
			16 6in. Q. F.	3,356	16 in 3 min.	286,379				
			6 4.7in. Q. F.	2,061	6 in 1 min.	74,196				
			36 smaller Q. F. taken as 20 12-prs.	423	10 in 1 min.	84,600				
			16 3-prs.	80.3		12,848				
						471,204				

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* This gun has an improved breech action, giving higher speed than former patterns. † English energies and rates of fire are used in default of the Russian ones. ‡ Mild steel.

REVIEW.

FACE-HARDENED ARMOR.

We have not had a suitable opportunity up to the present to comment upon a leading review of Lieutenant Ackerman's article in Number 73. The review will be found in full in the *Engineer* of May 24. Among other things it is stated there that "we are unable to accept his conclusions, which, in our judgment, lead to the substitution of rather a complicated and confused theory, and one which does not accord with results recorded, instead of the present one which is clear and on the whole fairly established. The main subject of the paper is the action of hard armor on shot striking it. Hitherto it has been supposed that a hard and well-supported surface resisted the shot before its point got deep enough in to receive support, and thus it frequently caused fracture or distortion of the shot. In this way the chilled iron shot formerly employed with such success against wrought iron broke almost like snowballs against the first steel-faced armor, and had to give place to steel projectiles."

The reviewer failed to note that Lieutenant Ackerman was not describing the action of chilled iron shot, but of the steel projectiles which took their place. In fact the effect of the typical face-hardened plate upon the projectile varies with the latter's quality. The conclusions of the essayist were based upon the results of hundreds of impacts of the best quality of modern armor-piercing projectiles, and to attempt to discredit those conclusions by citing the behavior of the inferior chilled iron shot seems absurd.

"Lieutenant Ackerman remarks that Captain Tresidder refers to 'data which he has seen fit to withhold,' which, he says, are widely different from the experience obtained in the States. It would be wrong to contradict this without knowing what experience is referred to, but we submit that Lieutenant Ackerman gives us no results in support of what he says. So far as we know, the results of trials in all countries bear out Captain Tresidder's explanation; and Lieutenant Ackerman's difficulty about what he calls the 'mashing of fragments in the indent' would, we think, be removed if he had had more experience with the earlier and inferior projectiles employed, when he would have seen what he regards as inexplicable realized *ad nauseam.*"

Here again the conclusions derived from numerous experiments with *bona fide* modern shells and armor are rejected in favor of those derived from the distantly analogous behavior of "the earlier and inferior projectiles employed." The photographs and descriptions of the four shells opposite pages 42 and 50 in the essay certainly support the writer's contentions. These shells are not isolated examples; they are typical of the behavior of all modern shells of their class and quality. Two of them are entirely too weak; it will be noticed, however, that the method of failure is not that described by Captain Tresidder and commented upon on page 50 of the essay. It will be noted that in the photographs noted the principal cracks are longitudinal and spiral, the points are abraded or fused, and the surface of the ogival flaked away; but the planes of cleavage do not at all agree with those described by Captain Tresidder. On page 44 of the essay is given a description and sketch showing the method of the failure of an ordinary very hard armor-piercing shell, such as was found very successful against oil-tempered steel armor. Many of these heads of projectiles have been shaken out of the plate by subsequent impacts, permitting a close inspection.

"Lieutenant Ackerman adds that the usual action of the hard face, however, is 'that through its inability to bend or flow, it prevents the displacement of the more plastic metal beneath it towards the front, and thus brings the resistance of the whole thickness of the plate to bear before the projectile can advance.' That is to say, the shot is not able to squeeze the metal up in a lip around it as it enters. It is true that this lip is not formed in hard-faced armor. Lieutenant Ackerman has done good service in calling attention to this, which has not been sufficiently noticed, perhaps; but we lay very limited stress on it, because compound or steel-faced iron plate formed no swell or bulge round the point of impact, and yet this armor was easily perforated until it had its face treated on Tresidder's process, when the projectiles were defeated and broken up. Those who have followed the course of experiments in this country can hardly fail to agree with Captain Tresidder's description of the phenomena exhibited in perforation."

The results of experiments on *bona fide* face-hardened armor are again discredited in favor of those obtained with inferior projectiles and obsolete compound armor. As the steel face of compound armor referred to contained about 1 per cent. of carbon, little, if any, flow of metal could occur in it. This lack of elongation, however, made it incapable of absorbing much energy; it cracked through under impact, and being held to the soft back only by a defective weld, was easily displaced and flaked off. The abrupt combination of the brittle hard face and extremely soft back was disadvantageous, for the two parts failed separately; the face having cracked away before the back had elongated to the point of maximum tenacity. The same is true of the compound plate when water hardened, only in that case the superficial hardness had been greatly increased and the remaining metal in the steel face had been improved and perhaps toughened. The method of resisting was really the same; no change had occurred in the back, but the resistance of the face had been increased, and it required a better projectile to perforate it. As the front third of the plate was, as before, of high carbon steel, it could not flow anyway, so it can hardly be said that it bottled up the resistance of the plate by preventing a forward displacement of the metal. In both cases, however, of the water-hardened and the untreated compound plates, the rigid face, when not displaced or flaked off, increased the resistance of the wrought-iron back by preventing the metal displaced by the projectile flowing to the front. When the hard face was displaced, concentric waves or bulges of the iron back were almost invariably found around the impact, showing that the soft metal had moved to the front in the direction of least resistance. Water tempering undoubtedly improves the tensile and compressive strength of the face of modern face-hardened armor enormously; in addition, it has greatly improved and toughened the metal in the body of the plate. A great deal of space has been given by Lieutenant Ackerman in the essay to these points. It will be noticed, however, that he has explained the resistance of the plate by describing the combined effect of a face of very great compressive strength with a strong and tough body. Necessarily this creates a complicated and difficult theory. It is very easy to say with the reviewer that the hard face breaks the projectile up from the point, and that the present theory " is clear, and on the whole fairly established "; but it may be asked, is not the present theory, requiring as it does not only a definition of *hardness*, but a full comprehension of the mutual behavior under impact of bodies of *unknown relative hardness*, far more difficult than the one proposed in the essay? F. Auerbach, in *Annalen der Physik und Chemie*, April, 1891, states that the subject of hardness " in its broader bearings has not yet been attacked with success, nor has a rigorous definition of hardness been established. . . . The edge of a rapidly rotating, relatively soft disc is scarcely touched by a file or lathe tool, and that if the motion be rapid enough, it is the tool which suffers most. . . . Hardness, when determined by scratching, is much too complex a conception to be used as a basis for the definition of the property. Complications are introduced by the motional phenomena, the lateral sheer which accompanies scratching, and in short, by conditions which have nothing to do with hardness." It is difficult to see how any theory involving a full comprehension of the property of hardness can be " clear " to any but the most easily satisfied and superficial of readers.

Again, " we believe that the real value of the cap is to prevent the fracture of the shot's point, and this has been endorsed, so far as we know, by facts; the matter, however, is easily brought to the proof. If Lieutenant Ackerman is correct, the value of a cap simply depends on whether the plate has a hard face which will not bulge or flow, while we believe that a shot which is able to hold together on impact will not benefit by a cap."

The four photographs of typical projectiles previously referred to support Lieutenant Ackerman's contention. Even in the case of the capped projectile which perforated the plate, the striations produced by the fragments of the hard face are plainly visible. In shell No. 262 the hard face was carried into the plate, enveloping the excellent point which escaped injury. The upsetting of the shell and the intense compression farther back where the most of the friction occurred, caused flakes of metal to be sheared off and the shoulder to be deeply scored. This shell held together, and would doubtless have done better with a lubricating cap. In the case of shells No. 160 and No. 15, it is plainly apparent that the points would not have been benefited by caps. These shells penetrated deeply, but the plate was able to absorb all their energy and stop them. Their points have been fused, abraded and twisted, but they certainly were not pulverized from the point. The results of many armor tests in the United States have been published with the photographs of projectiles which had perforated face-hardened armor, and it is a very common thing for a shell to hold together and perforate, although the abrasive action of the hard face wears the ogival down to a hemisphere.

"If Lieutenant Ackerman is correct, however, results ought to be forthcoming in support of his theory. For example, we witnessed certain Holtzer projectiles fired at untreated nickel-steel at Indianhead in 1893. These yielded and set up in a bulge round the projectile, at about half-way down, where the walls were apparently weakest. These projectiles might probably be made to set up and behave in the same way against treated armor, and if they could be made thus to behave, they ought, according to Lieutenant Ackerman, to benefit by having iron caps put on them. We shall be greatly surprised if shot so behaving can benefit by the addition of a wrought-iron cap. By all means let such a result be produced, as it will go far to establish our author's theory."

If the shell sets up or expands it will fail to perforate a face-hardened plate unless its energy greatly overmatches the resistance of the plate. In that case the shell would go through anyway. If the shell stops, however, the lubricant is of no use, for there is no friction. It does not appear that Lieutenant Ackerman states anywhere, inferentially or otherwise, that a cap would assist an expanded projectile in any other way than it assists one that retains its shape, that is, by "covering the asperities of the hardened metal." To be of any value motion is necessary.

"If the metal of the cap could be substituted for so much rigid metal round it in the plate, we should see a great benefit; but seeing that however it may accommodate itself to the hard fragments, the shot has to cleave its path open to the full size of its caliber, it may be doubted if the cap has helped it much."

This statement would seem to indicate a disbelief in the value of lubricants. From the table of tests with capped projectiles on page 52 it appears that the cap is of no appreciable value except when the uncapped shell would barely fail to perforate; the capped shell gets through merely because it is lubricated.

"We must now pass to Lieutenant Ackerman's proposal to employ armor plates with 'gashes' and ridges made in them, so as to facilitate cementation, and 'permit deeper chilling in hardening.' We may admire the inventor's defense of his proposal, which is too elaborate to give here, but we know the result we expect to follow. Projectiles may be broken up by such plates under favorable conditions, but the plates will fly into fragments; nay, we are tempted to say into 'smithereens,' as more expressive. Whatever result may be produced on the first shot, then we should anticipate that the structure will be stripped bare of its armor very rapidly; in fact, in spite of having learned much from the United States, we do not anticipate any future for 'gashed' plates."

It would have been well for the reviewer to have added: "The proof of the pudding, however, lies in the eating of it." On August the 13th last, a "gashed" plate 7 inches thick was tested at the Naval Ordnance Proving Ground. Fully 40 per cent. of the face was cut away at the points of impact by the gashes, which were about 1 inch deep. The plate did not represent in many important respects Lieutenant Ackerman's wishes. In the first place it had been over-carbonized, and the ridges were brittle hard through and through. It had been his intention, moreover, to forge the ridges down in the case of such thin plates. There were also other objections to the plate which had been made to test the feasibility and advantage, if any, of the various changes in the manufacture proposed, rather than to represent the ballistic value of the process. As a result, the methods proposed for a thick plate were applied to a thin one; nevertheless the plate, in spite of its disadvantages, behaved excellently, and compared very favorably with service plates of the same thickness. Two excellent 6-inch 100-lb. armor-piercing shell were fired at the gashed portion of the plate, one with a velocity of 1816 ft. s., and the other with a velocity of 2100 ft. s. The first penetrated about 5″.5, the second got its point through to the shoulder. Far from flying into fragments, the plate was not even cracked. A few fine hair cracks appeared in the hard surface in the immediate vicinity of the impacts, but the actual damage was confined to the closely circumscribing group of gashes.

The projectiles were excellent, as was shown by the fact that, although somewhat cracked, they were not crushed, remaining in the plate with their bases projecting.

BIBLIOGRAPHIC NOTES.

[AMERICAN.]

AMERICAN ENGINEER AND RAILROAD JOURNAL.

SEPTEMBER. The United States Cruisers Columbia and Minneapolis. H. M. S. Powerful. Aeronautics: the War Kite.

OCTOBER. Machinery for the New United States Torpedo-boats. Naval and Marine Notes. Aeronautics: Aeroplane Stability during Flight.

After November 1 the *American Engineer* will be published bi-weekly. Each number will contain one-half as much reading matter as is now contained in the monthly issue. The annual subscription rates will be reduced also.

NOVEMBER 1. The United States Battle-ship Indiana.

IRON AGE.

SEPTEMBER 12. A New Translucent Fabric.

OCTOBER 10. The Playford Stoker.

NOVEMBER 14. An Experimental Test of the Armored Side of U. S. S. Iowa.

NOVEMBER 28. The Improved Gatling Gun. The History of the Lathe.

DECEMBER 5. Report of the Secretary of the Navy.

DECEMBER 12. The Russell-See Electric Indicator.

This consists of a simple electric indicating and controlling mechanism which, when used on a vessel, will at all times keep the deck officer informed of the condition of his running lights.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

SEPTEMBER. The Army and the Civil Power. The Efficient Handling of Sea-Coast Artillery in Action.

The author handles this subject well from his own standpoint. He neglects the fact that the initiative will rest with the fleet, and that in case of a night attack the position of the fleet may be practically unknown, while that of the fort or forts is fixed. It may be assumed, as in serious attack of other defenses, that the attacking force will be much the stronger. Fog in these days of torpedo-boats and destroyers to act as scouts will not be an insuperable obstacle. It appears, however, that much will be expected of the fleet, but hardly more than will be expected of the sea-coast artillery, if it count on reproducing against a vigorous, intelligent enemy anything like the results of peace target-practice.

Any such accurate weapon as the 12″ B. L. mortar will probably be found in the fleet, and will be properly utilized against the land defenses. With high angle fire, in the neighborhood of 45° elevation (or other angle corresponding to maximum range), a degree more or less of elevation due to the roll of a ship will not cause much error, and the weight of the charge which determines the range is as controllable on sea as on land.

At the same time we heartily approve of coast defenses and accurate coast artillery fire. They cannot stop invasion, but may prevent bombardment of cities on the seaboard by ships; they will have a deterrent effect in any case, and are excellent as bases. Their value with a proper mobile force to act with them would be similar to that of Mantua in Napoleon's Italian campaigns. Napoleon says, "It is on the open field of battle that the fate of fortresses and empires is decided." He might have added after "battle," in view of his own fall, "*on sea or land.*"

Fortifications and Field Operations. Our Present Artillery Armament. The Man behind the Gun. The Bicycle as a Military Machine. Martial Law in Ceylon. Recruiting and Training of the Company. Modern Infantry Tactics. Modern War Conditions. Organization of Artillery Masses. Shock Power of the Service Bullet. Military Notes.

NOVEMBER. Can West Point be made More Generally Useful?

"Pursue this course: raise and keep the standard of admission to the Military Academy to the level of public school advantages throughout the land, thereby diminishing the number of cadets who fall by the wayside after entrance, while correspondingly increasing the number of graduates."

Extended Order. Military Education for the Masses. Artillery Organization. Military Reservations. The Bicycle for Military Uses. Ammunition Packing Boxes. The Equine Toilet. The Evolution of the Art of War. Twenty Years of Tactical Evolution in Germany. Examination for Promotion in England. German Theories upon the Utilization of the Local Resources by Troops in Campaign. The German and French Manœuvre Armies Compared.

JOURNAL OF THE UNITED STATES ARTILLERY.

JULY. Experiments with a New Polarizing Photo-Chronograph applied to the Measurement of the Velocity of Projectiles. The Development of a Naval Militia, by Jacob W. Miller, Commander, Naval Battalion, New York. Proposed Modification of the Field Gun Sight. Coast Artillery Fire Instruction. Light Artillery Target Practice.

OCTOBER. Experimental Use of the Essick Page Printing Telegraph for Transmitting Information in Sea-coast Artillery Firing, 1895. Notes on Confederate Artillery Service. Artillery Projectiles and their Penetration. Coast Artillery Fire Instruction. Note on a Photographic Method of Determining the Complete Motion of a Gun during Recoil.

[FOREIGN.]

ENGINEER.

JULY 26, 1895. Steam-Pipe Safety Valve. An Improved Siren. French War Vessels.

This article, while strongly condemnatory of the Hoche and Dupuy de Lôme, approves of the excessive "tumble-home" of their sides. Speaking of this latter and in regard to the British constructions, it says: "By its adoption, the side armor could be carried to a great height without seriously altering the metacentric features, and more effectual protection given to the gun's crews—a most important attribute in this day of rapid-fire warfare."

AUGUST 30. The Coast Defense French Battle-ship Bouvines. Trial Trip of the Russian Torpedo-boat Destroyer Sokol. Double Turrets for American Warships. [This article is a copy of that in the Army and Navy Journal.]

SEPTEMBER 6. The United States Naval Proving Ground at Indian Head. United States Experiments with a Polarizing Photo-Chronograph.

SEPTEMBER 13. Coal Consumption of H. M. S. Magnificent.

The results of the trial showed that with a mean of eighty-two revolutions of the engines per minute, maintained with a pressure of 133 lbs. per square inch in the boilers, the engines developed 6086 indicated horse-power, the coal consumed per horse-power per hour being 1.67 lbs. The boilers throughout the trial (of 30 hours' continuous duration) were worked with natural draught.

The Russian Torpedo-boat Destroyer Sokol.

OCTOBER 25. Launch of H. M. S. Victorious. H. M. S. Majestic.

The length of the Majestic between perpendiculars is only 390 ft., but, including the massive ram bow, which projects to a distance of 15 ft., and the hang-over of the stern and gallery, the total length over all is about 430 ft. The beam is similar to that of the Royal Sovereign class—75 ft. Hence the increased length has improved the speed of the new vessels, 17.8 knots per hour having been obtained with the Majestic, although the indicated horse-power is actually 1000 less than in the battle-ships of the 1889 programme. The displacement is 14,900 tons, exceeding that of any battle-ship afloat. The performances of the Majestic during her thirty hours' continuous trial were most satisfactory. Steaming gently, without any break, at an average rate of horsepower of 6075, she covered 440 knots in thirty hours; while, for every indicated unit of horse-power, she consumed only 1.84 lb. of coal per hour.

NOVEMBER 1. Steering Engines in the Royal Navy. Leading Articles: The Funnels of Warships; Coppering the Bottoms of Steel Ships. "The New Centurion," Longman's Magazine.

NOVEMBER 8. The Belleville Boiler and its Evaporative Efficiency. The Hanging of Harveyed Armor-Plates. Speed Trials of the New Argentine Cruiser Buenos Aires.

NOVEMBER 15. New Designs in Warships and Ordnance.

Advocates the introduction of the 8-inch B. L. R. into the British service in place of the 9.2-inch; as it is capable of being worked by hand-power, and marks the limit of the rapid-fire principle.

NOVEMBER 22. Launch of H. M. S. Jupiter.

ENGINEERING.

JULY 12. The Laws of Similitude as Affecting Naval Construction. On Water-Tube Boilers, by J. A. Normand.

AUGUST 2, 16, 23, and SEPTEMBER 6. The North-East Sea Canal.

SEPTEMBER 6. The Electric Lighting of the Entrance to New York Harbor. Coast Defense Artillery for Sweden and Norway [Whitworth 24 and 28-cm. guns]. Welin's Breech-loading Mechanism.

SEPTEMBER 13. The Sokol. Welin's Breech-loading Mechanism.

The threaded segments of the breech-block are arranged so that each successive segment has a radius larger than the preceding one, all but two out of eight being threaded. For a 10-inch B. L. R. there are twelve segments, ten being threaded. This construction makes the breech-block lighter.

SEPTEMBER 20. A New Smokeless Powder (Maxim-Schupphaus).

SEPTEMBER 27 and OCTOBER 18. The French Naval Manœuvres.

NOVEMBER 1. The Sokol (with illustration).

NOVEMBER 8. The Argentine Cruiser Buenos Aires (with photographs). The Work of Technical Societies. The Torpedo-boat Destroyers.

NOVEMBER 15. The United States Cruiser Minneapolis (illustrated). The Production of Modern War Material in the States.

NOVEMBER 22. The Torpedo-boat Destroyers Rocket, Shark, and Surly.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

AUGUST. The Royal Naval Reserve.

SEPTEMBER. On Torpedo-boat Destroyers. Kites: their Uses in War.

The conclusions of the author as published in the United Service Gazette were given in the last number of the Proceedings. The discussion following the lecture was not entirely favorable to the use of kites. Properly developed, they have undoubted value for naval purposes.

The Proposed Atlantic-Mediterranean Canal. Albuera.

OCTOBER. Water-Tube Boilers. The Colors of the Royal United Service Institution. The 14th Light Dragoons at Chillianwalla. The New Russian Armored Cruiser Rurik, with profile and deck plans.

NOVEMBER. Blockade in Relation to Naval Strategy, by Captain Mahan, U. S. N. Electric Propulsion and the Naval Service (translation).

The naval and military notes accompanying each of the above-mentioned numbers are very full, and are particularly interesting and instructive. In his various notes and reviews, the editor shows himself a keen and competent critic.

STEAMSHIP.

AUGUST, 1895. Another Unsinkable Boat.

Two short arms on each side of the boat, hinged at the water-line (for vertical plane movement), are kept ordinarily up the side of the boat and hold at their upper ends a suitable tube float. Two bent arms on each side, weighted at the ends, are similarly hinged at the gunwale, and by falling over the tube hold it to the side. If the boat capsizes, the float is free to move out from the side, and is prevented from going too far by a toe on each of the first-mentioned arms.

SEPTEMBER. Transmission of Electrical Power on board Ship.

For refrigerators, pumping and winding, auxiliary machinery, steering engines, capstans, ash-hoists, ventilating fans, ammunition lifts, training mechanism for guns, closing water-tight doors, air compressors for torpedo tubes. No design is given for an electric handy-billy.

OCTOBER. Launch of H. M. S. Venus. Steam Steering Engine for H. M. S. Venus. Speed Trials (contractor's) of H. M. S. Magnificent.

The speed was measured by log. The results for a four-hours' trial were: starboard engine 6002, and port 6155 indicated horse-power, vacuum 26.0 and 26.6; revolutions 99.8 and 100.8; speed 17.6 knots.

TRANSACTIONS OF THE NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

VOL. XI. Theory of the Rolling of Ships. Ship Acceleration and Fluid Resistance. The Transmission of Power by Electricity. The Application of the Electric Arc to Machinery and Boiler Repairs.

UNITED SERVICE GAZETTE.

JULY 13, 20 and 27. Types of Warships. [A consideration of a few of the types represented at Kiel.]

"The New York, which, notwithstanding the serious doubts the *Times* correspondent heard expressed on the point, may, we think, be assumed in all probability to be sufficiently stoutly built, is, in his opinion and in that of most naval critics, no unequal match for the Rurik. True, there is no armored protection immediately beneath either the turrets or barbettes of the New York; but, though the direct protection of the guns is deficient in some respects, it is far greater than in the Rurik."

JULY 27. The Shock Power of the Service Bullet.

It seems extremely doubtful whether the service bullet, small caliber, will give a sufficient shock to "stop" a man or horse.

AUGUST 17. The Naval Manœuvres (British).

AUGUST 24. Launch of the Prince George. The United States Cruiser Columbia.

The time of the run from the Needles to Sandy Hook was 6 days 23 hours 49 minutes. At the time of departure the quantity of coal on board was 1861½ tons, the draught forward was 26 feet 3 inches, aft 25 feet 6 inches. The total coal consumed was 1474 tons 1180 lbs.

The Recent Naval "Tactical Exercises."

"Previous naval manœuvres, with the partial exception of those of 1891, have always been of a strategic character. . . . It is now perceived that the so-called 'misconduct' which was punished with extreme severity in the earlier part of several eighteenth-century wars was not due, as was supposed, to want of loyalty or want of courage, but to insufficient acquaintance with the methods and principles of tactics and the defective signalling arrangements of the age. In the latter connection it is eminently satisfactory that a special effort was, during the recent 'exercises,' made to definitely ascertain the best methods of distant signalling. The rapidity with which modern vessels move renders this a most important point.

"One special lesson which the 'tactical exercises' just brought to a conclusion would seem to have demonstrated is, that vessels of very varying classes can be manœuvred together with far greater success than could have been reasonably expected."

SEPTEMBER 14. A New Polarising Photo-Chronograph (continued from the two previous numbers). Further Trials of the Sokol. Science in Warfare (Captain Sir Douglas Galton, K. C. B., in address as President of the British Association).

"But, great as have been the developments of science in promoting the commerce of the world, science is asserting its supremacy even to a greater extent in every department of war."

OCTOBER 12, 19. The Evolution of the Blue-Jacket (Vice-Admiral P. H. Colomb in the North American Review).

OCTOBER 26. The Trafalgar Anniversary. Launch of the Victorious. Proposed Emergency Ration for the American Army. Trafalgar's True Teachings.

NOVEMBER 23. The Problem of Modern Blockade. [A discussion of Captain Mahan's article in the Journal of the R. U. S. I.]

J. H. G.

LE MONITEUR DE LA FLOTTE.

AUGUST 31. The Japanese Victories.

"When, a year ago, the news of the battle fought off the mouth of Yalu was flashed all over the world, officers, writers, and publishers interested in naval affairs discussed the merits of that naval combat and sought in them logical lessons. This was, indeed, the first time that two fully equipped fleets met in action since the adoption of modern warships and armaments. It is just possible that an anxious desire to find in this battle profitable lessons for the future may have caused some to exaggerate the importance of its results, for neither side having fired high explosives, as wouldn't be the case with European navies, it is made clear that the lessons derived are far from conclusive.

Nevertheless, very interesting data have been gathered: the various incidents of the battle and the damages to the vessels engaged have demonstrated beyond a doubt the necessity of speed, in a tactical as well as in a strategic point of view, the efficiency of the quick-fire gun and the necessity of protection against its projectiles. Finally, it is shown that the navy of the Mikado possessed the qualities that make really efficient fleets, as well as able commanders, well-educated officers and efficient crews."

SEPTEMBER 7. The Sailors of the Imperial Guard.

An interesting memoir upon the naval battalion created by Napoleon I. as his body-guard at the time of the projected invasion of England.

SEPTEMBER 14-28. How to Make Ready for War. The Submarine Cables.

"What would be the situation in the case of a war breaking out suddenly between England and France is the momentous question agitating the minds of the French naval people."

OCTOBER 12. Names of the New Warships; New Constructions for 1896.

The programme includes an appropriation of 95,155,624 francs, the largest yet in any year. The Government will build six first-class battle-ships, one armored coast-defense, two first-class cruisers, five second-class cruisers, three third-class cruisers, one torpedo cruiser, two foreign station despatch boats, one despatch transport, one submarine boat—twenty-two vessels in all. To private yards will be awarded the construction of 3 battle-ships, 2 armored coast-defense vessels, 3 first-class cruisers, 4 second-class cruisers, 2 third-class cruisers, 2 high-speed cruisers, 1 torpedo-boat transport cruiser, 2 torpedo catchers, 2 gunboats, 1 torpedo despatch-boat, 5 sea-going torpedo-boats, 7 first-class torpedo boats, and 5 embarkable torpedo-boats.

The above programme has since been modified.

NOVEMBER 2. Battle Tactics.

"Noticing the absence in the navy of a prevalent fundamental principle (doctrine) in battle tactics, M. Marc Landry is of opinion that it would be expedient to fix upon invariable principles to serve as a basis for fleet commanders when making their final preparations for battle. There must be, he says, a certain set of common ideas, more or less general, enabling all those called upon to take part in an action to judge of the situation in the same spirit, to foretell the manœuvres of their colleagues, and as a consequence, to work with them in the prosecution of a common object, with a perfect understanding obtained without the necessity of signals. There are so many different opinions in regard to preparations for battle that it becomes an absolute necessity to rest upon well defined principles from which to deduce battle tactics, to be improved upon day after day by experience, until a solution is obtained that will be found nearest the truth. We humbly confess that such an ironclad doctrine does not appear to possess a positive advantage, and will still adhere to the well known principle of Nelson, that 'a commander will be always at his post when alongside of an enemy,' or Villeneuve's when he said that 'any captain not under fire is not at his post.'"

NOVEMBER 23. A New Press Campaign in England in Favor of an Increase of the Navy.

"It is very likely a repetition of the campaigns of 1888 and 1893, with the same object in view." Speech of M. Lockroy, the new minister of marine, to the personnel of his Department.

REVUE DU CERCLE MILITAIRE.

AUGUST 31. Cyclists as Cavalry Auxiliaries.

SEPTEMBER 7. Infantry, and the Artillery Duel.

SEPTEMBER 14. Army Group Manœuvres (map). Infantry, and the Artillery Duel (cont.).

SEPTEMBER 28. Reforms in the War Office.

OCTOBER 5. How to Court Defeat (a study). Reforms in the War Office.

OCTOBER 12. A Comparison between the French and German Grand Manœuvres.

OCTOBER 19. The Folding Bicycle at the Grand Manœuvres of 1895. The New Fire Drill Regulations. Manœuvre of the Medical Service Corps.

OCTOBER 26. How to Court Defeat (cont.). The Folding Bicycle at the Grand Manœuvres of 1895. Manœuvre of the Medical Service Corps.

NOVEMBER 2. Garrison Manœuvres for Officers of the Reserve and the Territorial Army. The Folding Bicycle, etc. (with map).

NOVEMBER 9. Opinions of a Russian Officer about the French Army. Coast Defenses. The Folding Bicycle at the Grand Manœuvres (with map) (ended).

NOVEMBER 23. The New German Cavalry Regulation (see also Nov. 16). Military Hygiene.

REVUE MARITIME ET COLONIALE.

SEPTEMBER. On the Advantage of a Systematic Reorganization of the Naval Establishment. On the Stability of Small Vessels in a Heavy Sea. Statistics of Wrecks and Other Sea Mishaps for the year 1893 (cont.). A Study of the Laws of Storms.

OCTOBER. A Study of the Electric Gyroscope. Grave Defects of High Speed Cruisers. The Grounding of the Sardegna. Opinion of an Officer regarding the Raleigh and Cincinnati.

Not efficient war vessels. Intense heat in their fire-rooms. Too much machinery; too little coal; crews' berthing inadequate.

NOVEMBER. The Italian Colonies. Circulation of Winds and Rain (supplementary and explanatory notes) (ended). Influence of Sea Power on History (1660-1783) (cont.), translated from the English).

LE YACHT.

AUGUST 31. Modern Naval Tactics: Opinions of the English Press. (Lieut. Leplay, of the French Navy, published *in extenso* an article on the above subject in the Revue Martime et Coloniale (1895)).

SEPTEMBER 7. Modern Naval Tactics (see preceding No.). The America's Cup. Organization of the Transport Service between China and Indo-China.

SEPTEMBER 14. Modern Naval Tactics: Opinions of the American Press.

SEPTEMBER 21. Experimental Determination of the Least Resistance Form of Hull.

SEPTEMBER 28. The New 23-knot Cruisers, and the Next Naval Constructions. The Question of Auxiliary Transport Vessels. Experimental Determination of the Least Resistance Form of Hull. The Cost of Warships in England. Perception of Phonic Signals.

OCTOBER 5. The 31 Knots of the Twin Screw Torpedo-boat Forban (a detailed account of the official trials). The First-class English Cruiser Terrible.

OCTOBER 12. The Net Cost of Warships in England. The Armored Coast Defense Vessel Sachsen, of 7438 Tons. The English First-class Cruiser Terrible.

OCTOBER 26. The New Torpedo-boats and Torpedo Catchers.

NOVEMBER 2. The Naval Reforms.

NOVEMBER 9. The Navy Estimates, by Marc Landry.

NOVEMBER 16. The Navy Reforms and the New Administration.

RIVISTA DI ARTIGLIERIA E GENIO.

JULY-AUGUST. Method of Sighting and Pointing in Coast Batteries. Training of the Personnel of Coast Artillery. The New Disinfecting Establishment at Hamburg.

SEPTEMBER. Notes on the Fire Drill of Field Artillery. A Note upon the Manner of Removing Incrustations in the Interior of Drinking Water Pipes.

OCTOBER. Correction for Each Piece of the Distance obtained by the Range-Finder in Coast Firing. The Automatic Tangent Scale. About Armor Plates and their Behavior under Fire.

RIVISTA MARITTIMA.

OCTOBER, with Supplement, and NOVEMBER. The Sailing Routes of the China Seas. Maritime Meteorology. The Side Keels for Large Ships. Tactical Use of Torpedo-boats. The Military Situation in the Mediterranean.

REVISTA TECNOLÓGICO-INDUSTRIAL.

AUGUST. Applications of Cinematic Geometry; The Mathematical Infinite in the Direct Acting Steam Engine. Altimetry; Measuring Altitudes by Means of the Barometer, Hipsometer, and Photogrameter. The Heights of Many Spots in Catalonia.

BOLETIN DO CLUB NAVAL.

AUGUST 30. Coast Defenses (cont.). Feed-Water for Boilers. Gas Pressure of Powders in the Chamber of the Gun. Determination of the Temperature of Combustion of Explosives. Submarine Photography.

BOLETIN DEL CENTRO NAVAL.

JUNE-JULY. The Projected Dockyard at La Plata. Compulsory Military Service (considerations on which is founded the project). Brief Historical Notes on Modern Naval Warfare. Steel for Ordnance (cont.).

AUGUST. The Cruise of the Argentina; a Glorious Page in the Argentine Naval History. The Naval Fêtes at Kiel. Remarks on Battle-ships, Cruisers and Guns. Installation of Krupp Guns of 28 cm. in the Bays of Valparaiso and Talcahuano. Destroying the Felix Patagonia Reef that obstructed the Channel of the Riachuelo. J. L.

DEUTSCHE HEERES ZEITUNG.

SEPTEMBER 14. The New Cruisers (Ersatz Freya) K and L.

SEPTEMBER 18. The Offensive and Defensive Weapon in the Battle of the Yalu. Determination of the Fighting Value of a Vessel (method of Captain Bettolo, of the Italian Navy).

SEPTEMBER 28. Carrier Pigeons.

Experiments were recently conducted in Sweden to discover whether the noise and concussion of the guns during a naval engagement have any effect upon the carrier pigeons, especially upon their localizing powers. It was shown that, during or even shortly after a heavy cannonade, the liberated birds failed to take up their flights, and were evidently so stunned as to incapacitate them for some time. The importance of this point must not be neglected in dealing with the question of carrier pigeons.

MARINE RUNDSCHAU.

OCTOBER, 1895. Necessity of Regular Physical Exercises for Naval Officers.

Dwells on necessity of physical exercise. A horizontal bar and parallel bars can be easily set up on board ship. Daily exercise is needed; also jumping. Apparatus easily rigged on deck. Fencing with foil and broadsword. Dumb-bell and Indian club exercises are recommended above all others; can be easily carried out on board ship. Riding on horseback and bicycle, rowing and swimming, long-distance swimming, and swimming fully clad is recommended. Walking, mountain-climbing, running.

Fog Signals Indicating Course of Vessels.

A review of the different forms of delivering fog-signals to indicate courses steered. A satisfactory solution of the problem has not yet been obtained. It is difficult to decide which of the systems is the best, that embodying a combination of short and long blasts for different quadrants, or that containing a combination of blasts in different keynotes, such as bass and treble. The most difficult point will always be the determination of the direction and distance of the signalling vessel. Until this determination is accurately established by some invention, the use of fog horns, sirens and whistles to indicate courses steered will be limited.

NOVEMBER. The Education and Assignment of Specialists from the Corps of Naval Officers. Estimating Distances.

MILITÄR WOCHENBLATT.

SEPTEMBER 7, 1895. Africa: Some Observations on the Effects of Bullets from the Military Rifle M/88.

In two cases where horses were struck without injuries to vital parts or bones the wounds healed very rapidly. In both cases the wounds caused by exit of the bullet were but slightly larger than those of entrance. And it appears that if the bullet pierces soft parts, without touching nerves or larger blood-vessels, it will leave the body in same shape and size as in entering. Also in hunting large game it was found that unless struck in the head, heart, backbone or bones of the legs, the bullet is insufficient to stop the game. Even with shots through lungs, body, etc., larger animals are able to run for great distances after being struck, and frequently get away.

OCTOBER 5. New Italian Warships.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOLUME XXIII., No. 10. Progress in Armor and Ordnance during 1894 (Karl Pfeiffer, Lt. of Artillery). III. Artillery in the Battle of the Yalu. H. G. D.

REVIEWERS AND TRANSLATORS.

Lieut. J. H. GLENNON, U. S. Navy. Lieut. H. G. DRESEL, U. S. Navy.
Prof. JULES LEROUX.

EXCHANGES.

American Chemical Journal.
American Engineer and Railroad Journal.
Army and Navy Journal.
Army and Navy Register.
Bulletin of the American Geographical Society.
Bulletin of the American Iron and Steel Association.
Bulletin of the Geographical Society of California.
Cassier's Magazine.
Colliery Engineer.
Electrical Engineering.
Engineer (New York).
Engineering-Mechanics.
Geological Survey of Missouri.
Iron Age.
Journal of the American Society of Naval Engineers.
Journal of the Association of Engineering Societies.
Journal of the Franklin Institute.
Journal of the United States Artillery.
Journal of the United States Cavalry Association.
Journal of the Military Service Institution of the United States.
Lend-a-Hand.
Littell's Living Age.
Occasional Papers of the California Academy of Arts and Sciences.
Proceedings of the American Philosophical Society.
Railroad Gazette.
School of Mines Quarterly.
Scientific American.
Stevens Indicator.
Technology Quarterly and Proceedings of the Society of Arts.
Transactions and Proceedings of the Geographical Society of the Pacific.
Transactions of the American Society of Mechanical Engineers.
Transactions of the American Institute of Mining Engineers.
Transactions of the American Society of Civil Engineers.
Transactions of the Connecticut Academy of Arts and Sciences.
Transactions of the Technical Society of the Pacific.
United Service.
Annalen der Hydrographie und Maritimen Meteorologie.
Boletin del Centro Naval.
Boletin do Club Naval.

Deutsche Heeres-Zeitung.
Engineer.
Engineering.
Journal of the Royal United Service Institution.
Journal and Proceedings of the United Service Institution of New South Wales.
Le Moniteur de la Flotte.
Marine-Rundschau.
Militär Wochenblatt.
Minutes and Proceedings of the Institution of Civil Engineers.
Mittheilungen aus dem Gebiete des Seewesens.
Mémoires et Compte Rendu des Travaux de la Société des Ingenieurs Civils.
Norsk Tidsskrift for Sovaesen.
Proceedings of the Royal Artillery Institution.
Proceedings of the Institution of Mechanical Engineers.
Revista Maritima Brazileira.
Revista Tecnológico Industrial.
Revue du Cercle Militaire.
Revue Maritime et Coloniale.
Rivista di Artiglieria e Genio.
Rivista Marittima, Rome.
Steamship.
Teknisk Tidskrift.
Tidskrift i Sjöväsendet.
Transactions of the Canadian Institute.
Transactions of the Canadian Society of Civil Engineers.
Transactions of the Institution of Naval Architects.
Transactions of the North of England Institute of Mining and Mechanical Engineers.
Transactions of the North-East Coast Institution of Engineers and Shipbuilders.
United Service Gazette.
Le Yacht.

THE NAVAL WAR COLLEGE.

We have had occasion before to refer to the place in our naval system filled by the Naval War College. Probably no argument for its existence could be more convincing than the fact that the excellent works of Captain Mahan in the domain of strategy were there originated under the mainspring of duty, being delivered as a series of lectures to the College. As an afterthought, probably at the suggestion of some one who had a keen business instinct, they were delivered to the world, to appear, as they do, in the opinion of many of the great present leaders in thought, among the most wonderful literary productions of the 19th century. Such work is, of course, exceptional, but represents a standard which in future will be approached more or less nearly by those who will control the destinies of the College.

To show that there is no "lagging behind" in present contemplation, and at the suggestion of the President of the U. S. Naval Institute, we print the following circulars and order for the benefit of those members and subscribers who have not received them.

SPECIAL CIRCULAR }
No. 20. }

NAVY DEPARTMENT,
WASHINGTON, February 18, 1895.

1. The session of the Naval War College and Torpedo School for 1895 will commence on the first day of June next, and will terminate on the 15th day of October.

2. It is the intention of the Department to detail a class of about twenty-five officers (fifteen of and above the grade of lieutenant and ten below that grade) for attendance during the session. From this class it is proposed to select five officers to remain after the session to continue the general work through the winter and prepare for the next session. These five officers will be chosen for their aptitude in the work, and their attainments in International Law, Strategy, and Tactics.

3. The location of the principal problem of the session of 1895 will be the Cape Cod vicinity and a small section north of it. A beginning also will be made of a general strategic consideration of the Gulf of Mexico.

H. A. HERBERT, *Secretary.*

SPECIAL CIRCULAR }
No. 22. }

NAVY DEPARTMENT,
WASHINGTON, D. C., November 15, 1895.

The methods of work of the Naval War College as at present carried on having proved satisfactory, the Department directs that the following programme be carried out, in order that subjects shall be taken up in the order of their importance.

The study of the various portions of our coast, as examples of strategic and tactical conditions, will be continued by the permanent staff of the College. Reconnaissances will be undertaken when necessary, and such systematic exercises with launches, war games and problems as shall perfect a thorough preparation for the summer sessions.

During 1894 the session was devoted to—

1. From the Delaware to Cape Cod; and during 1895 to—
2. Cape Cod to the Penobscot.

Beginning the 1st of January, 1896, the programme will include in the order given—

UNDER COAST DEFENSE.

3. The Gulf of Mexico.
4. Delaware and Chesapeake Bays.
5. The lower lakes (Erie, Ontario, Champlain).
6. Puget Sound and Alaskan waters.
7. San Francisco to San Diego.
8. The coast from Cape Hatteras to Eastport, Maine, comprising the three sections already studied.

IN STRATEGY.

1. All strategic questions concerned in the above developments of our coast defense.
2. Special study of the strategy of the Gulf of Mexico and its vicinity.
3. Strategy of the Caribbean Sea.
4. The strategic features of the North Pacific and the Aleutian Islands.

IN NAVAL TACTICS.

1. The search for the most *desirable battle tactics.*
2. The best *formations* for the fleet for such *tactics.*
3. The *types of vessels* most suited for those formations.
4. *Tactical studies* of our coast and preparation for the naval defense of important localities.
5. The construction of *war charts* and the preparation of *defense plans.*

In the consideration of these subjects the methods now in use will be followed. These are, during the winter season, a study of naval and military history; the use of war games to assist in determining disputed questions in strategy and tactics, the frequent solution of strategic and tactical situations, and the exercising with steam launches.

During the summer sessions the officers in attendance will follow these lines and will in addition prepare solutions of special problems in the defense of our coast. There will also be a course of lectures bearing upon naval warfare and international law, by officers or civilians of special knowledge on these subjects.

The solutions of the problems in naval warfare studied at the Naval War College and the resulting confidential detailed plans when completed will be filed at the Navy Department.

H. A. HERBERT, *Secretary.*

SPECIAL ORDER }
No. 40. }

NAVY DEPARTMENT,
WASHINGTON, D. C., November 15, 1895.

1. The session of the Naval War College for 1896 will commence on the 1st day of June, and terminate on the 1st day of October.

2. It is the intention of the Department to detail twenty-five officers, twenty of and above the grade of lieutenant, and five below that grade, for attendance during the session.

3. From this class it is proposed to select five officers, upon the recommendation of the college, to continue the work of the college during the winter, and to prepare for the next year's session.

4. The officers detailed will therefore be selected when possible from those who have a year or more to serve on shore duty.

5. The location of the principal problem of the session of 1896 will be the Gulf of Mexico.

6. The construction of a war chart and defense plan of the Nantucket Sounds will be completed, and the general strategic consideration of Delaware and Chesapeake Bays will be begun.

H. A. HERBERT, *Secretary*.

OFFICERS OF THE INSTITUTE,

1896.

Elected at the regular annual meeting, held at Annapolis, Maryland, October 11, 1895.

President.

REAR-ADMIRAL S. B. LUCE, U. S. N.

Vice-President.

CAPTAIN PHILIP H. COOPER, U. S. N.

Secretary and Treasurer.

LIEUTENANT J. H. GLENNON, U. S. N.

Board of Control.

LIEUT.-COMMANDER B. F. TILLEY, U. S. N.
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LIEUTENANT C. E. COLAHAN, U. S. N.
LIEUTENANT J. P. PARKER, U. S. N.
LIEUTENANT H. G. DRESEL, U. S. N.
PROFESSOR N. M. TERRY, A. M., Ph. D.
LIEUTENANT J. H. GLENNON, U. S. N. (*ex-officio*).

SPECIAL NOTICE.

NAVAL INSTITUTE PRIZE ESSAY, 1897.

A prize of one hundred dollars, with a gold medal, is offered by the Naval Institute for the best essay presented on any subject pertaining to the naval profession, subject to the following rules:

1. The award for the prize shall be made by the Board of Control, voting by ballot and without knowledge of the names of the competitors.

2. Each competitor to send his essay in a sealed envelope to the Secretary and Treasurer on or before January 1, 1897. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary and Treasurer, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Board.

3. The successful essay to be published in the Proceedings of the Institute: and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Board of Control; and no change shall be made in the text of any competitive essay, published in the Proceedings of the Institute, after it leaves the hands of the Board.

4. Any essay not having received honorable mention, may be published also, at the discretion of the Board of Control, but only with the consent of the author.

5. The essay is limited to fifty (50) printed pages of the Proceedings of the Institute.

6. All essays submitted must be either type-written or copied in a clear and legible hand.

7. The successful competitor will be made a Life Member of the Institute.

8. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

By direction of Board of Control.

J. H. GLENNON,
Lieut., U. S. N., Secretary and Treasurer.

ANNAPOLIS, MD., *Dec.* 31, 1895.